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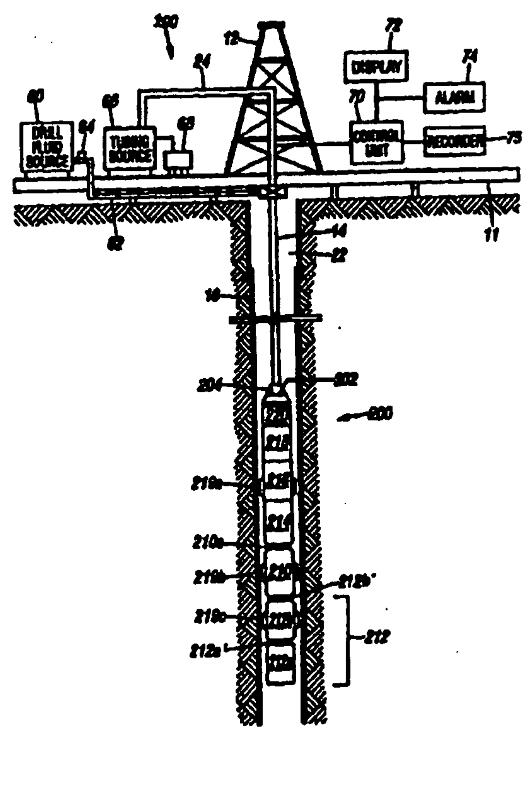
(54) Title: APPARATUS AND METHOD FOR PERFORMING IMAGING AND DOWNHOLE OPERATIONS AT WORK SITE IN WELLBORES

(57) Abstract

The present invention provides a downhole service tool for imaging a location constituting a work site of interest downhole at which a tool operation is to be performed in a preexisting wellbore and for performing a tool operation at the work site during a single trip of the tool. The downhole service tool includes an imaging device which sensors properties associated with the work site and generates data representative of the work site. The imaging data is transmitted to the surface via a two-way telemetry system. An end work device in the downhole service tool performs the desired tool operation at the desired work site. The service tool images the work site, communicates imaging data to the surface and performs the desired operation during a single trip into the wellbore.



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## PATENT APPLICATION

TITLE: APPARATUS AND METHOD FOR PERFORMING IMAGING AND DOWNHOLE OPERATIONS AT WORK SITE IN WELLBORES

### Field of the Invention

This invention relates generally to downhole tools for use in wellbores and more particularly to tools which can image a work site or an object in a wellbore, communicate with the surface and perform a desired end work or service at the work site, during a single trip in the wellbore. The present invention also provides novel imaging devices and end work devices and various downhole tool configurations for imaging worksites and performing the desired end works.

### Background of the Invention

To produce hydrocarbons (oil and gas) from the earth's formations, wellbores (also referred to in industry as boreholes) are formed to desired depths. The shallow portion of the wellbore is typically large in diameter, which is lined with a metal casing to prevent caving of the wellbore. The wellbore is then drilled to a desired depth to recover hydrocarbons from the subsurface formations. After the wellbore has been drilled, a metal pipe, generally referred to in the art as the casing or pipe, is set in the wellbore by injecting cement

through the annulus between the casing and the wellbore. Branch or lateral wellbores are frequently drilled from a main wellbore to form deviated or horizontal wellbores for improving production of hydrocarbons from the subsurface formations.

A large proportion of the current drilling activity involves directional drilling, i.e., drilling deviated and horizontal wellbores, to improve the hydrocarbon production and/or to withdraw additional hydrocarbons from the earth's formations. The wellbores are then completed and put into production. The drilling and completion processes involve a number of different operations. Such operations may include cutting and milling operations (including cutting relatively precise windows in the wellbore casings), sealing junctures between intersecting wellbores, welding, re-entering lateral wellbores, perforating, setting devices such as plugs, sliding sleeves, packers and sensors, remedial operations, sealing, stimulating, cleaning, testing and inspection including determining the quality and integrity of a juncture, testing production from a perforated zone or a portion thereof, collecting and analyzing fluid samples, and analyzing cores.

Oilfield wellbores usually continue to produce hydrocarbons for many years. Various types of operations are performed during the life of producing wellbores. Such operations include removing, installing and replacing different

types of devices, including fluid flow control devices, sensors, packers or seals, remedial work including sealing off zones, cementing, reaming, repairing junctures, milling and cutting, freeing stuck sleeves, diverting fluid flows, controlling production from perforated zones, setting sleeves, and testing wellbore production zones or portions thereof.

Typically, to perform downhole operations at a work site in a preexisting wellbore, whether during the drilling, completion, production, or servicing and maintaining the wellbore, a desired tool is conveyed downhole, positioned into the wellbore at the work site and the desired operation is performed. Most of the prior art tools are substantially mechanical tools or electro-mechanical tools. Such tools lack downhole maneuverability, in that the various elements of the tools do not have sufficient degrees of freedom of movement, lack local or downhole intelligence, do not obtain sufficient data with respect to the work site or of the operation being performed, do not provide an image of the work site during the trip made for performing the end work, and do not provide confirmation of the quality and integrity of the work performed. Such prior art tools usually require multiple trips downhole to image a work site, perform an operation and then to confirm whether the operation has been properly performed. Multiple downhole trips can be very expensive, due to the rig or production down time.

The present invention addresses some of the above-noted problems and provides downhole service tools (also referred to as the downhole tool or service tool) which can be positioned and oriented adjacent a desired work site, images of the work site to the surface, perform the desired work at the work site and confirm or inspects the quality of the work during a single trip into a preexisting wellbore. The present invention provides imaging devices, end work devices and various downhole tool configurations to image work sites and to perform desired operations in preexisting wellbores. The imaging devices include an optical viewing device, an inflatable imaging device, ultrasonic devices and a tactile device. The end work devices include cutting devices, reentry devices, sealing devices, welding devices, testing and servicing devices.

## SUMMARY OF THE INVENTION

The present invention provides a downhole tool for imaging a location constituting a work site of interest in a preexisting wellbore and for performing a tool operation at the work site during a single trip in the wellbore. The downhole tool includes an imaging device for imaging the work site and an end work device for performing a desired operation or an end work at the work site. The imaging device may determine the image downhole and transmit the image to the surface or transmit the image data for processing at the surface. The downhole tool may be conveyed into the wellbore by any suitable method,

including a wireline, a tubing, and a robotics device that moves the downhole tool inside the wellbore.

Any suitable imaging device may be utilized for the purpose of this invention, including a camera for optical viewing, microwave device, contact device (tactile device) such as a probe or a rotary device, an acoustic device, ultrasonic device, infra-red device and radio frequency ("RF") device.

The end work devices may include a fishing tool to engage a fish downhole, whipstock, diverter, re-entry tool, packer, seal, plug, perforating tool, fluid stimulation tool, fluid fracturing tool, milling tool, cutting tool, patch tool, drilling tool, cladding tool, welding tool, deforming tool, sealing tool, cleaning tool, tool for installing a device, tool for removing a device; setting device, testing device, an inspection device, acidizing tool, an anchor, and a tool that engages with a downhole object.

In the downhole tools of the present invention, one or more devices are provided to position and orient the imaging device and the end work device as desired. Each downhole tool preferably includes a computer or processor and associated memory for storing therein models and programs for controlling the operations of the imaging device and the end work device. A surface computer receives the data from the downhole tool and displays the image of the work

site for use by an operator. A two-way telemetry system provides communication between the surface computer and the downhole tool.

The present invention also provides ultrasonic imaging devices, including a device which can image radially and downhole (in front) of the downhole tool. In one mode, the ultrasonic imaging device transmits signals by sweeping a preselected frequency range to obtain an effective operating frequency. The device then continues to operate the transmitter at such effective frequency to generate data representative of the attributes of the work site.

The present invention also provides an imaging device for obtaining still and/or video pictures of a work site in the wellbore. This viewing device includes a camera or another suitable device for taking the pictures and a mechanism to displace the non-transparent fluid in the wellbore with a transparent fluid. This invention further provides an inflatable device for providing the image of an object in the wellbore when such device is inflated and urged against the object.

The downhole tool may further include sensors for providing information about the condition of the downhole tool in the wellbore. Such sensors may include sensors for determining temperature, pressure, fluid flow, pull force, gripping force, tool centerline position, tool configuration, inclination, and

acceleration. Formation evaluation sensors and other sensors to log the wellbore may also be included in the downhole tool of the present invention.

The present invention also provides certain end work devices, including a high pressure fluid cutting tool, which includes a source of supplying a fluid at a relatively high pressure and a cutting element for discharging the high pressure fluid. The fluid source may include serially arranged pressure stages, wherein each such stage increases the fluid pressure above its preceding stage. The fluid may be pulsed prior to supplying it to the cutting element. A control unit controls the position and orientation of the cutting element relative to the work site. The control unit may be programmed to cut according to a predetermined pattern provided to the control unit.

In each of the downhole tools of the present invention, the operation of the imaging device and the end work device may be controlled from the surface and/or by the computer or processor in the downhole tool.

Examples of the more important features of the invention have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims

appended hereto.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed understanding of the present invention, reference should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, and wherein:

**FIGS. 1** and **1A** are schematic diagrams of a system utilizing a service tool conveyed into a wellbore for imaging a work site in the wellbore and performing a desired operation at the work site during a single trip according to one embodiment of the present invention.

**FIG. 2** is a schematic diagram of a pressurized fluid cutting tool as an end work device for use in the system of **FIG. 1**.

**FIG. 2A** shows a manner of positioning the cutting element of the cutting tool shown in **FIG. 2** in a wellbore to cut material located downhole of the cutting tool.

**FIG. 2B-C** show alternative ways to position the cutting element of the downhole cutting tool shown in **FIG. 2** to cut materials located downhole of the

cutting tool.

**FIG. 3** is an example of a predetermined profile of a section of the casing to be cut that may be stored in a memory associated with the cutting system of **FIG 1**.

**FIG. 4** is a schematic diagram of the cutting tool shown in **FIG. 1** with a downhole imaging device for obtaining images of areas to be cut before and after the cutting operation.

**FIG. 5A** is a schematic diagram of an embodiment of a downhole (service) tool having an ultrasonic imaging sensor for imaging a work site downhole of the service tool and an end work device for performing a desired operation at the work site during a single trip.

**FIG. 5B** is a schematic diagram of an alternative embodiment of a downhole tool having an ultrasonic imaging sensor for radially imaging a work site and an end work device for performing a desired operation at the work site during a single trip.

**FIG. 5C** is a schematic diagram of yet another embodiment of a downhole service tool having an ultrasonic imaging sensor for radially imaging a work site

and an end work device for performing a desired operation at the work site during a single trip.

**FIG. 5D** shows the downhole service tool of **FIG. 5A** positioned adjacent a wellbore juncture desired work site in a preexisting wellbore.

**FIG. 6A** shows a schematic diagram of an embodiment of an imaging tool for obtaining still and/or video pictures of object downhole.

**FIG. 6B** shows a schematic diagram of the imaging tool of **FIG. 5D** positioned adjacent to a juncture between a main wellbore and a branch wellbore.

**FIG. 6C** shows a schematic diagram of an inflatable imaging tool position at a wellbore juncture for determining a contour of the juncture.

**FIG. 6D** shows a configuration of the placement of sensors in the inflatable member used in the imaging tool of **FIG. 5F**.

**FIG. 7** is a schematic diagram of an embodiment of a downhole tool having an imaging device and a milling tool disposed at a bottom end of the tool for imaging a work site and performing a milling or cutting operation at the work

site during a single trip.

**FIG. 8A** is a schematic diagram of an embodiment of a downhole tool having an imaging device and an end work device for use in lateral wellbore operations.

**FIGS. 8B-8D** are schematic diagrams of downhole tools with an imaging device and re entry device.

**FIG. 9** is a schematic diagram of an embodiment of a downhole tool having an imaging device and an inflatable packer wherein the imaging device is adapted to obtain images during setting of the inflatable packer in a wellbore.

**FIGS. 10A-10B** are schematic diagrams of an embodiment of a downhole service tool having an imaging device and a welding device disposed for imaging a work site and performing a welding operation at the work site.

**FIG. 11** is a schematic diagram of an embodiment of a downhole tool having an imaging device and an end work device for pressure testing the integrity of a juncture.

**FIG. 12** is a schematic diagram of an embodiment of a downhole tool for

performing testing of a perforated zone.

**FIG. 13** is a schematic diagram of an embodiment of a downhole tool having an imaging device and an end work device for performing rework operations in wellbores.

**FIG. 14** is a schematic diagram of an alternative embodiment of a downhole tool according to the present invention for performing cementing, fracturing and squeeze-off operations in wellbores.

**FIGS. 15-16** are schematic diagrams of embodiments of a downhole tool for performing fishing operations in wellbores.

**FIG. 17** is a schematic functional block diagram relating to the general operation of the downhole imaging and servicing tools of the present invention.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

**FIG. 1** is a schematic diagram of a system **100** for use in oilfield wellbores for imaging a work site, communicating data about the image to the surface and performing a desired operation (endwork) at the work site during a single trip in the wellbore. The system **100** includes a downhole service tool

200 (also referred to herein as the downhole tool or the service tool) conveyed from a platform **11** of a rig **12** into a wellbore **22** by a suitable conveying device **24** from a source **66** thereof, such as a reel, being operated by a prime mover **68**. As an example, and not as any limitation, **FIG. 1** shows the conveying device **24** to be a coiled-tubing. Other conveying methods, such as wireline or robotics devices may also be utilized. The upper end **202** of the service tool is connected to the tubing **24** via a suitable connector **204**. During operations, a drilling fluid from a source thereof **60** may be supplied to the wellbore **22** by a pump **68**.

A surface control unit **70** placed at a suitable location on the rig platform **11** preferably controls the operation of the system **100**. The control unit **70** includes a suitable computer and memory for processing data, providing selected information to an operator on a display **72**, including images of the work site, logs during tripping of the wellbore, location (depth) of the tool **200** in the wellbore and orientation of the various elements of the service tool **200** in the wellbore **22** and values of selected tool, formation and wellbore parameters. The data from the service tool **200** may be transmitted to the surface by a suitable data link (telemetry) and recorded by a recorder **75** for later use. Suitable alarms **74**, coupled to the control unit **70**, are selectively activated by the control unit **70** when certain operating parameters exceed their respective limits. The operation of control units, such as the control unit **70**,

is known and is, thus, not described in detail herein.

The service tool **200** includes one or more imaging devices or image sensors **210** for imaging work sites downhole, one or more end work devices **212a-212b**, one or more control mechanisms (hydraulic or electro-mechanical) **214** for controlling the operation of the end work devices **212a-212b** and/or the imaging devices **210**. The tool **200** may also include other sensors and devices, generally denoted herein by numeral **216**, for determining desired parameters or characteristics relating to the tool **200** and the wellbore **22**. Such sensors and devices may include devices for measuring temperature and pressure inside the tool **200** and in the wellbore **22**, sensors for determining the depth of the tool in the wellbore **22**, position (x, y, and z coordinates) of the tool **200**, inclinometer for determining the inclination of the tool **200** in the wellbore **22**, gyroscopic devices, accelerometers, devices for determining the pull force, center line position, gripping force, tool configuration and devices for determining the flow of fluids downhole.

The tool **200** further may include one or more formation evaluation tools for determining the characteristics of the formation surrounding the tool in the wellbore. Such devices may include gamma ray devices and devices for determining the formation resistivity. The tool **200** may include devices for determining the wellbore inner dimensions, such as calipers, casing collar

locator devices for locating the casing joints and determining and correlating tool **200** depth in the wellbore **22**, casing inspection devices for determining the condition of the casing, such as casing **16** for pits and fractures. The formation evaluation sensors, depth measuring devices, casing collar locator devices and the inspection devices may be used to log the wellbore while tripping into and or out of the wellbore **22**.

The service tool **200** preferably includes a central electronic and data processing unit or downhole control unit or circuit **218** for receiving signals and data from downhole devices, processing such data, communicating with the surface control unit **70** and for controlling the operations of the downhole devices. The control unit **218** preferably includes one or more processors (micro-controllers or micro-processors) for performing data manipulation according to programmed instructions provided thereto from the surface or stored in memory in the downhole tool **200**.

The service tool **200** preferably includes a two-way telemetry **220** that includes a transmitter for receiving data including the image data, from the control unit **218**, downhole sensors and devices and transmits signals representative of such data to the surface control unit **70**. Any suitable transmitter may be utilized for the purpose of this invention including an electro-magnetic transmitter, a fluid acoustic transmitter, a tubular fluid transmitter, a

mud pulse transmitter, a fiber optics device and a conductor. The telemetry system **220** also includes a receiver which receives signals transmitted from the surface control unit **70** to the tool **200**. The receiver communicates such received signals to the various devices in the tool via the control unit **218** as explained later in reference to **FIG. 17**.

Still referring to **FIG 1**, the imaging sensor or device **210** may be any suitable sensor including a camera for optical viewing, microwave device, contact device (tactile device), such as a probe or a rotary device, an acoustic device, ultrasonic device, infra-red device, or RF device. The imaging sensor **210** may be a non-contacting device, such as an ultrasonic device, or a contacting device that has one or a series of projections from the tool **200** that engage with the wellbore and objects in the wellbore. If the quality or resolution of the image of the work site provided by the imaging device **210** depends, at least in part, on the frequency of the transmitted signal by the imaging device **210**, then it is preferred to adapt the device to sweep the frequency in a predetermined range of frequencies to determine an effective frequency and then obtain the image at such effective frequency. The imaging sensor **210** may be employed to provide a still or motion picture of a work site or an object downhole, or to determine the general shape of the object or the work site or to distinguish certain features of the work site prior to, during and/or after the desired operation has been performed at the work site.

Still referring to **FIG. 1**, the end work devices **212a** and **212b** may include any device for performing a desired operation at the work site in the wellbore. The end work device **212a-212b** may include a fishing tool adapted to grab a fish downhole, whipstock, diverter, re-entry tool, packer, seal, plug, perforating tool, fluid stimulation tool, fluid fracture tool, milling tool, cutting tool, drilling tool, workover tool, testing tool, cementing tool, welding tool, an anchor, acidizing tool or inspection tool. As noted earlier, one or more end work devices **221a-212b** may be included in the tool **200** for performing the desired operations at one or more work sites in the wellbore. Use of certain of these devices with an imaging sensor is described below as examples.

Additionally, the service tool **200** may include downhole controllable stabilizers **219a** and **219b**, each such stabilizer having a plurality of independently adjustable pad segments for providing lateral movement and lateral stability to the tool **200** and for anchoring the tool **200** in the wellbore **22**. Such stabilizers are especially useful in deviated and horizontal wellbores. A plurality of independently controlled outwardly extending arms **219c** may be utilized to provide lateral movement and stability to the tool **200** within the wellbore **22**. For a majority of the downhole imaging and servicing applications the end work device utilized is designed for the specific application. In some applications, several end work devices may be incorporated into the service tool **200**. To provide desired degrees of freedom for each of the end work devices **212a-212b** and the imaging device **210**, such devices are coupled to the tool

via knuckle joints, such as joints, **212a,'** **212b'** and **210a** respectively. The movement of such knuckle joints is preferably controlled by the control unit **218**. The degrees of freedom present in the tool **200** and the type of image sensor utilized preferably allow obtaining the image of any work site in the wellbore.

The service tool **200** is preferably modular in design, in that selected devices in the tool are individual modules that can be interconnected to each other to assemble the desired configuration of the tool **200**. It is preferred to form the image device **210** and the end work devices **212a-212b** as modules so that they can be placed in any order in the tool **200**. Also, each of the end work devices **212a-212b** and the image device **210** have independent degrees of freedom so that the tool **200** and any of the devices can be positioned, maneuvered and oriented in the wellbore in substantially any desired manner to perform the desired downhole operations.

The service tool **200** may be conveyed into the wellbore by a wireline, a coiled-tubing, a drill pipe, a downhole thruster or locomotive for pushing the tool **200** into a horizontal wellbore or a robotics device on the tool to move and guide the service tool in the wellbore.

As shown in **FIG. 1A**, the end work device **212'** or any other device in

the tool **220** may have independently controlled downhole movements, such as shown by the solid lines **212' a** and dotted lines **212' b**, which allow the device **212'** to be positioned at any angle in the wellbore **22**. Thus, the service tool **200** can be positioned adjacent to a work site in a wellbore, image the work site, communicate such images online to the surface, perform the desired work at the work site, and confirm the work performed during a single trip into the wellbore.

As noted-above, the system **100** may utilize any number of different imaging devices and end work devices. A number of such tool combinations are described below. Prior to describing such tools, a novel cutting and milling device and imaging sensors are first described while referring to **FIGS. 2-4**.

**FIG. 2** shows a schematic diagram of the system utilizing a novel high pressure fluid cutting device or tool **20** for cutting and milling materials in the wellbore **22** according to one embodiment of the present invention. In general, the cutting tool includes a cutting element such as a nozzle, for discharging a relatively high pressure fluid to cut the member. A source of supplying the high pressure fluid in the downhole tool provides the high pressure fluid to the cutting element. The cutting element may be continuously positioned and oriented at the desired location about the member to be cut by a control circuit contained in the downhole tool and/or at the surface.

The cutting tool **20** has a tubular housing (body) **26**, which is adapted for connection with the conveying device **24** via a suitable connector **202**. The housing **26** contains the various elements of the cutting tool **20**, which include a cutting element section **28**, a power section **34** for supplying pressurized fluid to the cutting element section **28**, a control unit **36** which controls the vertical and radial position of the control element **28** and a downhole control unit **38** for housing the circuits and memories associated with the downhole tool **20**.

The bottom section **28** of the housing **26** houses a cutting element **30** that terminates in a nozzle or probe **30a** suitable for discharging a relatively high pressure fluid in the form of a jet stream of a relatively small cross-sectional area. For the majority of downhole cutting or milling applications, water discharged at a pressure greater that 60,000 psi is adequate in removing materials from within a wellbore. In cutting pipes, which are more than one-half inch thick, higher pressure may be required. The section **28** preferably rotates about the joint **32**, which connects the section **28** with a hydraulic power section, generally denoted herein by numeral **34**.

The power section **34** preferably includes a plurality of serial sections $P_1$-$P_n$, each of which increases the pressure of a fluid above the pressure of the preceding section by a predetermines amount. The last section $P_n$ discharges the fluid into the cutting element **30** at the desired pressure. The power section

**34** also may contain a device **33** which pulses the fluid at a predetermined rate before it is supplied to the cutting element **30**. High pressure pulsed jet stream is generally more effective in cutting materials than non-pulsed jet streams. The cutting element **30** may be a telescopic member that is moved along the tool's longitudinal axis z-z (axially) within the section **28** which enables positioning the probe **30a** at the desired depth adjacent to the wellbore. In an alternative embodiment, the section **28** may be fixed while the nozzle **30** may be rotated radially about the tool longitudinal axis. The above described movements of the cutting element **30** provide multiple degrees of freedom, i.e., along the axial and radial direction thereby allowing accurate positioning of the nozzle **30** at any desired location within the wellbore.

A section **36** contains devices for orienting the nozzle tip **30a** at the desired position. The cutting element section **28** is rotated about the wellbore axis to radially position the nozzle tip **32a**. The cutting element **30** is moved axially to position the nozzle tip **30a** along the wellbore axis z-z. Hydraulically operated devices or electric motors are preferably utilized for performing such functions. The section **36** also preferably includes sensors for providing information about the tool inclination, nozzle position relative to the material to be cut and relative to one or more known reference points in the tool. Such sensors, however, may be placed at any other desired locations in the tool **20**. In the configuration shown in **FIG. 2**, the cutting element **30** can cut materials

along the wellbore interior, which may include the casing or an area around a junction between the wellbore **22** (main wellbore) and a branch wellbore, as shown in **FIG. 4**. To cut the casing **23**, the cutting element **30a** is positioned at a desired location. As the tool **20** starts to cut the casing **23**, it is rotated to circumferentially cut the pipe. If concentric casings are present, the fluid pressure may be increased accordingly to cut concentric pipes.

**FIG. 2A** shows a configuration of a cutting element **30'** that may be utilized to cut materials below the cutting tool **20**. In this configuration, the probe **30a'** discharges the fluid downhole of the tool **20**. Arrows **A-A** indicate that the cutting element **30'** may be moved radially while the circular motion defined by arrows **B-B** indicates that the cutting element **30'** may be moved along a circular path within the section **28'**. The cutting element configuration shown in **FIG. 2A** is useful for performing reaming operations in a tubular member, such as a production tubing, which are required when interior of such tubing is lined with sediments.

To remove a permanent packer difficult to remove, it is desirable to remove (cut away) only the packing elements and the associated anchors, if any, which typically lie between a packer body and the wellbore interior. The packers and anchors typically engage the casing at areas that are relatively smaller than the tool body. Prior art tools typically cut through the entire

packer, which can take excessive time. The packers can readily be removed by only cutting the packing elements and any associated anchors disposed between the packer and the casing. In such applications, the cutting nozzle needs to be positioned over the packing element alone. **FIGS. 2B-C** show a configuration of the cutting element **30"** whose nozzle **30a"** may be placed at any desired location above a packing element within the wellbore and then rotated to cut through the such element below the nozzle. Arrows **C-C** indicate that the probe **30a"** may be moved radially within the section **28"** while circular path defined by arrows **D-D** indicate that the cutting element may be rotated within the wellbore. **FIG. 2C** shows the position of the cutting element **30"** after it has been moved radially a predetermined distance. As is seen in **FIG. 2C**, the nozzle tip **30a"** extends beyond the section **28"** which will allow the tool **20** to cut a material anywhere below the tool **20**.

Electrical circuits and downhole power supplies for operating and controlling the operation of the cutting element **30**, the power unit **34**, and the devices and sensors placed in section **34** are preferably placed in a common electrical circuit section **38**. Electrical connections between the electrical circuit section **38** and other elements are provided through suitable wires and connectors. The surface control unit **70** preferably controls the operation of the cutting system **10**.

The operation of the cutting system **10** will now be described with respect to cutting a section or window in a casing while referring to **FIGS. 2** and **3**. The tool **20** is conveyed downhole and positioned such that the nozzle is adjacent the section to be cut. The stabilizers **40a-b** are set to ensure minimal radial movement of the tool **20** in the wellbore **22**. A cutting profile **80** (**FIG. 3**) defining the coordinates for the outline of the section to be cut is stored in a memory (not shown) associated with the system **10**. Such memory may be in the downhole circuit **36** or in the surface control unit **70**. An example of such outline is shown in **FIG. 3**. The arrows **82** define the vectors associated with the profile **80**. The profile **80** is preferably displayed on the monitor **72** at the surface. An operator orients the nozzle tip **30a** at a location within the section of the casing to be cut. The desired values of the fluid pressure and the pulse rate are input into the surface control unit **70** by a suitable means. The tool **20** is then activated to generate the required pressure and the pulse rate. The fluid to the tool **20** is preferably provided from the surface via the tubing **24**. Alternatively, the wellbore fluid may be used.

If the section to be cut is such that it will remain in position after it has been cut, perhaps due to the presence of a cement bond, or if the cut section can be dropped to the wellbore bottom as debris, then the system **10** may be set so that the nozzle tip **30a** will follow the profile **80**, either by manual control by the operator or due to the use of a computer model or program in the

system. If the section must be cut into small pieces or cutting so that they may be transported to the surface, the cutting element is moved within the profile at a predetermined speed along a predetermined pattern, such as a matrix. This method ensures that the casing section will be cut into pieces that are small enough to be transported to the surface by circulating a fluid through the wellbore. During operations, the downhole circuits contained in the section **38** communicate with the surface control unit **70** via a two-way telemetry. The downhole telemetry is preferably contained in a section **39**.

**FIG. 4** shows the downhole cutting tool of **FIG. 2** with an imaging device **90** attached below the cutting section **28**. Any suitable imaging device may be utilized. The imaging device **90** is utilized to confirm the shape of the section of the casing or the junction after the cutting operation has been performed. The imaging device **90** may also be utilized to image the area to be cut to generate the desired cutting profile and then to confirm the cut profile after the cutting operation. This enables the imaging of a location at a work site of interest and the performance of desired operation at the work site in a preexisting wellbore. Other types of downhole service tools may be utilized for imaging a location in a wellbore at which a tool operation is to be performed and performing the desired tool operation at the work site without retrieving the tool from the wellbore. Certain downhole end work devices are described later.

**FIGS. 5A-5C** show embodiments of downhole ultrasonic imaging devices for use with an end work device to image a work site of interest and to perform a desired operation at the work site during a single trip into the wellbore.

**FIG 5A** shows a downhole service tool **250** having an end work device **252** for performing a desired operation downhole, an ultrasonic device **260** (ultrasonic imaging sensor) placed downhole of the end work device **252** for imaging a work site or an object in the wellbore. The imaging device **260** has a number of sensor elements **264** arrange on a body. Each sensor element **264** acts as a transmitter and receiver. The preferred frequency range is between 100 KHz and 500 KHz. The ultrasonic transmitter is preferably adapted to sweep the frequency within a predetermined range of frequencies. The signals transmitted by the sensor element **264** are reflected back from the work site or the object and the reflected signals are received by the sensor elements **264**, which are processed by the control unit **256** or circuit in the tool **250** and transmitted uphole via telemetry **258** to provide an image of the work site.

The ultrasonic sensor **260** may be rotated or beam steered (i.e. electrically rotating or directing) to scan the inside of the wellbore. The ultrasonic signals are transmitted at a predetermined rate and the reflected signals are received by the sensor elements **264** between successive firings of the transmitter. The end work device **252** may include a work element **253**

that may be rotated by device **254** along the arrows **252a** to orient the work element radially and may be moved vertically as shown by the arrows **252b**, i.e., longitudinally to move the work element **253** uphole or downhole, which enables positioning the work element at any desired location in the wellbore. The sensor **260** and the end work device **252** are independently rotatable. The sensor **260** may be disposed above the end work device **252**.

As shown in the tool **250'** of **FIG. 5B**, the sensor elements **264'** may be arranged on the body **255** of the end work device **252'** around the end work element **253'**. The sensor elements **264'** may be disposed in any desired manner to image a segment of the wellbore or the entire wellbore interior. The tool may be moved along the directions denoted by arrows **252a' and 252b'**. The vertical length of the sensor elements **264'** and the spacing there between defines the vertical imaging sweep and the resolution. Similarly, the horizontal distance of the sensor elements **264'** and the spacing between the sensor elements defines the radial sweep and the resolution. Alternatively, sensor elements may be arranged on the tool to direct signals downhole, as shown in **FIG. 5C** here the sensor elements **264"** are disposed at the downhole (bottom) end of a service tool **250"**. This enables the service tool **250"** to image an object or a work site downhole of the service tool **250"**.

**FIG. 5D** shows the downhole service tool **250**, shown in **FIG. 5A**,

positioned adjacent to a juncture **304** between a main wellbore **300** and a branch or lateral wellbore **302**. The tool **250** may be utilized to image the juncture **304** and perform an operation thereat. The tool **250** provides an image of the juncture **304** to the surface prior to performing an operation. The image may be utilized to position the tool **250** at the desired location and to appropriately orient the tool **250** adjacent the juncture **304** . The desired operation may then be performed at the juncture **304**, which may include a window cutting operation, reaming operation, cementing, welding, sealing or any other desired operation.

**FIG. 6A** shows a schematic diagram of a system **710** for obtaining still and/or video images of a wellbore interior or an object in the wellbore. The system **710** includes a downhole tool **720** that contains a camera for taking pictures of the work site and a mechanism for displacing the non-transparent fluid around the work site with a transparent or substantially transparent fluid. For convenience and ease of explanation and understanding, and not as a limitation system **710** shows only the imaging device, i.e. without any end work device.

The system **710** includes a downhole imaging tool **720** conveyed from a platform **11** of a derrick **12** into a wellbore **122** by a suitable conveying device **124**, such as a tubing or wireline. The imaging tool **720** has a tubular housing

726, which is adapted for connection with the conveying device 724 via a suitable connector 719. The housing 726 contains the various elements of imaging tool 720. The bottom section of the housing 726 contains a camera section 728, which houses a retractable camera 730. The camera 730 may be moved within a camera housing 732 by a hydraulic means or an electric means, such as motor, generally denoted herein by numeral 734. The electrical circuits and downhole power supplies for operating and controlling the camera movements are preferably placed in a common electrical circuit section 736. Electrical connections between the camera section 728 and the electrical circuit section 736 are provided through suitable wires and connectors between the two sections. The camera 730 in its retracted position, as shown by the solid lines 730, may be sealed from the outside environment by closing a hatch or door 738. The hatch may be adapted to open outward as shown by the dotted line 738a or by a sliding door (not shown). In the fully retracted position, the camera 730 resides completely inside the housing 728 so that the hatch 738 may be closed to seal the camera 730 from the outside environment.

In the fully extended position, the camera 730 extends far enough from the camera section 728 or any other obstruction, as shown by the dotted line 730a, so that the camera 730 can be rotated 360 degrees and can take unobstructed pictures of its surroundings. A light source 740 attached near the camera provides sufficient light for the camera to obtain pictures downhole.

Additional light sources (not shown) may be provided on the tool body **726** to provide light in all the directions. The camera **730** may be focused downward as shown in **FIG. 6A** or horizontally as shown in **FIG. 6B** or along any other desired direction depending upon the intended application.

The imaging tool **720** contains a fluid injection section **744** for injecting a substantially transparent fluid (herein referred to as the clear fluid) into the wellbore. The fluid injection section **744** is preferably placed above (uphole) the camera section **728**. The fluid injection section **744** includes one or more chambers, such as **746a** and **746b**, for storing therein the clear fluid. A pump **746** in the section **744** is used to controllably inject the clear fluid from the chambers **746a-746b** into the wellbore below the camera section **728** via a fluid line **748**. The fluid line **748** runs from the fluid injection section **744** through the camera section **728** to an outlet point **748a** below the camera section **728**. Any downhole electrical control circuits and related power supplies for operating the pump **746** are preferably housed in the electrical section **736**.

A surface control unit **770** placed at a suitable location on the rig platform **711** preferably controls the operation of the imaging system **710**. The control unit **770** includes a suitable computer, associated memory, a recorder for recording data and a display or monitor **772**. The operation of control units, such as the control unit **770**, is known and is, thus, not described in detail

herein.

The operation of the imaging system **710** will now be described in reference to obtaining an image of an object, such as object **750**, stuck in the wellbore **722**. To obtain the image of the object **750**, the location of the object is first determined. A number of techniques have been utilized in the oilfield applications for determining the location of an object or work site in a wellbore. Any such technique or method may be utilized for determining the location of the object **750** for the purposes of this invention. The tool **720** is then conveyed into the wellbore **722** until the bottom end **752a** of the fluid return pipe **752** is below the surface **750a** of the object **750** that is to be imaged. The packer **733** is then inflated or set in the wellbore **722** to seal the wellbore section **722a** below the camera section **728** from the wellbore section **722b** above the packer **733**. The pump **746** is then activated from the surface control unit **770** to inject the clear fluid from the chambers **746a-b** into the wellbore section **722a** via fluid line **748**. The injection of the clear fluid into the section **722a** causes the wellbore fluid present in the section **722a** to enter the fluid pipe **752**, which fluid is discharged into the wellbore section **722b** above the packer **733** via a port **752b**. This processes is continued until the wellbore fluid between the port **752a** and the camera section **728** has been replaced with the clear fluid. The clear fluid chosen is preferably lighter than the wellbore fluid and will not mix with the wellbore fluid. Such a clear fluid when injected into

the wellbore section **722a** will uniformly displace the wellbore fluid. In some applications, it may be necessary to continue to inject additional clear fluid so as to completely flush out the wellbore fluid from section **722a**. The system of the present invention may employ a clear fluid source at the surface (not shown) instead of downhole chambers. In this embodiment, the clear fluid is continuously supplied to the chamber **746** from a surface source via a line placed in the conveying means **724**. Such a system may be necessary when large quantities of clear fluid are required to flush out the wellbore fluid.

After the object **750** has been exposed to the clear fluid, the camera door **738** is opened and the camera **730** is lowered to its fully extended position **730a**. To obtain the images of the object **750**, the camera lights **740** are activated, the camera **730** is oriented in a desired position and the camera is operated to obtain images of the object **750**. The images from the camera are transmitted by the downhole control circuits in section **736** to the surface control unit **770** via a two-way telemetry **725**. The images are displayed on the monitor **772**. The operator can orient the camera in any desired direction and continue to obtain images. If a video camera is used, the motion pictures are displayed on the monitor. The images are recorded in the recorder associated with the surface control unit **770**.

**FIG. 6B** shows the application of the imaging system **710** described

above in reference to **FIG. 5D** for obtaining images of a junction **760** between a main wellbore **722** and a branch wellbore **723**. To obtain images of the junction **760**, a packer **735** is first set in the wellbore **722** below the junction **760** to completely seal off the wellbore section **22c** lying below the packer **35**. The imaging tool **720** is then conveyed in the wellbore **722** so that the packer **33** is completely above the junction **760** while the port **752a** of the fluid return line **752** is below the junction **760**. The imaging tool **720** is operated as described earlier to displace the wellbore fluid in the wellbore section **722a'** between the packers **733** and **735** with the clear fluid. The camera **730** is then oriented in the direction of the junction **760** to obtain the desired images. Images of other objects in the wellbore and any section of the wellbore may be obtained by the imaging system **710** in the above-described manner.

**FIG. 6C** shows another embodiment of a downhole imaging tool **800**. The imaging tool **800** includes a flexible inflatable device **810** at a lower end of the tool **800**. A fluid injection system **812** in the tool **800** injects a fluid into the device **810**, thereby inflating the device **810**. The fluid injection system **812** preferably contains a fluid pump section **814** having a reversible pump therein for injecting or pumping a fluid from a chamber **816** into the device **810** and vice versa.

**FIG. 6D** shows a cross section of the flexible inflatable device **810**. It

includes a bladder **840** made from a flexible material, such as rubber. A plurality of sensors **842** are arranged along the inner surface **840a** of the bladder **840** in a matrix or grid as shown in **FIG. 6D**. Each such sensor provides a signal corresponding to the deformation of the bladder surface to which the sensor is attached from a predetermined norm. The signals from each such sensor are transmitted to a downhole control circuit **816** via a conductor **844** and communication link **848**. Fluid line **846** provides access to the bladder inside **840a**. The downhole control circuit **816** controls the operation of the pump section **812**, receives data or signals from the each of the sensors **842**, conditions the signals and may manipulate the signals to obtain an image. The downhole control circuit **816** may transmit the conditioned signals to a surface control unit, such as unit **970** shown in **FIG. 17**, which produces the image based on a model stored in the control unit. The model is predetermined or predefined based on the geometry of the flexible member **810** and the configuration of the sensors **842**. The model is stored in a downhole memory associated with the downhole control circuit **816** when the system is designed to compute the model downhole.

Operation of the tool **800** will now be described in the context of obtaining an image of a junction between the main wellbore **822** and the branch wellbore **823**. To obtain an image of the junction **860**, the tool **800** is conveyed into the main wellbore **822** until the flexible member is adjacent to the

junction **860**. The fluid from the fluid section **812** is then injected into the flexible member **810**, thereby inflating the member **810**. A portion of the flexible member at the junction **860** attains the shape that corresponds to the junction **860** outline. The downhole control circuit **816** measures the signals from each of the sensors **842** and processes such signals as described above to obtain the image of the junction. Image of an object in the wellbore, such as object **850** shown in **FIG. 6B**, is obtained by inflating the flexible member **810** while urging it against the object.

**FIGS. 7 - 16** show embodiments of certain downhole tools which are adapted to image a work site of interest and perform a desired operation at work sites in a pre-existing wellbores during a single trip according to the present invention.

**FIG. 7** shows an embodiment of a downhole service tool **350** conveyable by a tubular member **356**, such as a drill pipe. The end work device **352** is a milling device and is disposed at the bottom end of the conveying member **356**. A suitable imaging device **354** is disposed above the milling device **352**. A conduit **358** may be utilized to supply hydraulic or electric power to the tool **350**. A control unit, other sensors, and associated electronic circuitry and telemetry may be disposed in the tool **350** as described earlier. During operation, the work site or the object to be milled is imaged by the imaging

sensor **354** and the cutting operation is performed by the milling device **352**. Images of the area being cut are periodically obtained to ensure that the cutting operation is being performed correctly. Other end work devices, such as tools for determining the widow seal integrity may be disposed with the milling device **352**.

**FIG. 8A** shows a downhole service tool **370** that may be utilized to image a location in the wellbore **375** and then drill the lateral wellbore **377** and/or to facilitate re-entry of an end work device into the lateral wellbore **377**. To drill the lateral wellbore **377**, the tool **370** is positioned above a whipstock or any other suitable re-entry device **379**. An image device **380** provides images of the location where the lateral wellbore **377** will be drilled, which image may be utilized to position and orient the drilling element (bit) **372**. Alternatively, since the image is available, the operator can set kick-off devices **382** to cause the device **372** to perform an operation at a juncture **377a** without first requiring the installation of the re-entry device **379**, thereby avoiding another trip downhole. The tool **370** may similarly be used to reenter the wellbore **377** to perform secondary operations in the branch wellbore **377**, thereby eliminating an extra trip to install the re-entry device **379**.

**FIGS. 8B and 8C** show another embodiment of a downhole service tool **385** which can be utilized to enter a branch wellbore **377** from a main wellbore

**375** without the use of a re-entry device, such as a whipstock or a diverter. The downhole service tool **385** includes an end work device **386** at the service tool **385** downhole end, a suitable imaging device **387** and a downhole operated tool orientation device **388**. The device **388** preferably is a hydraulically or electrically operated knuckle-type joint which bends the tool **385** portions above and below the device **388** up to a predetermined maximum angle. The service tool **388** is lowered into the main wellbore **375** to a known distance above the juncture **377a**. The image device **387** provides images of the juncture **377a**. The operator then orients the tool **385** and activates the device **388** to bend the tool **385** at a predetermined angle. The device is locked into the bent position and the tool **385** continues to be lowered into the wellbore. Inserting the tool **385** further causes it to enter into the branch wellbore **377** as shown in **FIG. 8C.**

Once the bottom end device **386** has entered into the branch wellbore **377**, the device **388** is unlocked, which allows the front portion of the tool **385** to straighten as it moves further into the branch wellbore **377**. After the tool **385** has been conveyed to the desired work site in the branch wellbore **377**, the end work device **386** is then utilized to perform the desired operation. Thus, the service tool configuration of **FIGS. 8B-8C** allows the operator to (a) convey the service tool **385** into a branch or lateral wellbore **377** without the use of a secondary device, such as a diverter, and (b) image a desired work site in the

branch wellbore and perform a desired operation at the work site in a single trip. This service tool **385** can eliminate two downhole trips, one to install a diverter, such as the diverter **379** shown in **FIG. 8** and a second trip to image the work site prior to performing the work at the work site.

**FIG. 8D** shows an alternative device **390** for causing the service tool **385** to enter the branch wellbore without the use of a diverter. The device **390** includes a plurality of arms or members which can be independently extended outward from the service tool body to urge against the wellbore wall **375a**. Selectively urging the members **392** against the wellbore wall **375a** causes the tool to enter the branch wellbore **377**.

The knuckle-joint **388** shown in **FIG. 8B** and the arm members **392** shown in **FIG. 8D** are operated by their respective control units in the service tool **385**. The downhole control unit (**FIG. 1**) controls the operation of these devices based on instructions provided from the surface control unit **70** or downhole stored programmed instructions. The service tool may also be programmed to locate the juncture **377a** and cause the tool **385** to enter the branch wellbore **377**. Thus, the service tool shown in **FIGS. 8B-8C** can locate a lateral or multilateral juncture, adjust or orient itself and penetrate the lateral wellbore without the use of additional devices, such as diverters and whipstocks, and thereafter perform an end work in the lateral wellbore during

a single trip downhole.

FIG. 9 shows an embodiment of a service tool **400** with an imaging device **420** and a packer **410** as the end work device. The service tool **400** is shown conveyed by a tubular **402** into an open hole **404**. The packer **410** has an inflatable packer element **412**, which when inflated seals an annulus between the packer **410** and the wellbore **404**. The packer **410** is attached to the tubular **402** by a shear bolt **406** having a weak point **406a** that may be sheared to separate the packer **410** from the tubular **402**. An imaging device **420**for imaging the annulus **407** between the packer **410** and the wellbore **404** is placed above the shear point **406a**.

To set the packer element **412** in the annulus **407**, the tool **400** is positioned in the wellbore **404** so that the packer **410** is across from the area **407**. The packer **410** is set by injecting a hardening fluid, such as cement, epoxy, or another suitable material, into the packer element **412**. If an acoustic device is used as the imaging device, its response characteristics are a function of the manner the annulus is being enclosed with the hardening material. The data from the imaging device **420** is analyzed to determine the quality of the bond between the packer element **412** and the formation **404**. Based on the imaging characteristics, the amount of the hardening material being supplied to the packer element **412** can be adjusted to improve the integrity of the seal.

After the packer **410** has been set, the bolt **406** is sheared to retrieve the service tool **400** from the wellbore **404**.

**FIGS. 10A** and **10B** show examples of embodiments of downhole service tools for imaging a work site of interest and performing welding operations at the work site during a single trip in the wellbore. **FIG. 10A** shows the service tool **450** for welding a juncture **434** between a casing **430** in a main wellbore **435** and a casing **432** in a branch or lateral wellbore **437**. The service tool **450** includes a welding device **452** at its bottomhole end. The service tool **450** may also include a milling device **456** to dress or smooth any rough welding performed by the welding device **452**. An image device **458** is preferably placed above the welding device **452** and the milling device **456**. The welding device **452** is coupled in the tool **450** with a rotatable joint **453**. Similarly, if a milling device **456** is utilized, it is preferably disposed in the service tool **450** via rotatable joints **455a** and **455b**. The rotatable joints **453**, and **455a** and **455b** allow the welding device **452** and the milling device **456** to independently rotate in the wellbore **435**. The service tool **450** also includes a control unit **461** to position and orient the tool **450** in the casing **430** and other desired devices **462**. A central processor **460** processes signals and data from the downhole devices and communicates with the surface computer **70** (**FIG. 1**) via a two-way telemetry **464**.

To weld the casings **430** and **432** at the juncture **434**, the service tool **450** is conveyed into the casing **430** by a suitable conveying system **451**. The imaging device **456** provides an image of the juncture **434** to the surface control unit **70** (FIG. 1). The welding device **452** is positioned adjacent to the juncture **434**. The welding tip or probe **454**, having its own degrees of freedom, is positioned at the juncture to perform the welding operation. The probe **454** may be extended radially and/or axially to position the probe **454** at any desired location in the casing **430**. The axial movement of the service tool **450**, rotary movement of the joint **453** and the axial and radial movements of the probe **454** provide necessary degrees of freedom of movement to position the welding probe **454** at any desired spot in the casing **430**. One or more downhole-controlled and independently-operated stabilizers or radially extendable arms **466** or any other suitable device may be utilized to urge the probe **454** against the juncture **434** to be welded.

The image device **456** may be utilized to image the juncture **434** after welding operations or intermittently during welding operations to ensure quality and integrity of the welds **434a**. The tool **450** may then be repositioned to place the milling device **456** adjacent to the weld **434a**. The milling device **456** has a milling surface **456a** on its outside, which is extended outwardly and urged against the weld **434a** to smooth out the weld **434a**. Any suitable milling device, including any commercially available mechanical milling device may be

utilized in the service tool **450**.

**FIG. 10B** shows a manner of utilizing the service tool **450** for welding a device **470**, such as a permanent packer, a plug, or a plate below the plate inside a casing **475**. To weld the device **470** inside the casing **475**, the service tool **450** is placed above the device **470** to image the work site **471** to be welded. The tool **450** is then repositioned to place the welding probe **454** against the area **471**. The welding operation is then performed in the manner described above. It should be noted that only one type of welding device has been described above to perform selected welding operations to describe the concept of the invention. Any other suitable welding device may be utilized with the service tool **450** to perform any type of welding operations.

**FIGS. 11** and **12** show a service tool **500** for performing testing operations in the wellbore. **FIG. 11** shows a configuration for testing the integrity of a seal. In the example of **FIG. 11**, a seal **514** is placed in a lateral wellbore **512** formed from a main wellbore **510**. The service tool **500** is shown conveyed into the main wellbore **510**. It includes a suitable imaging device **502**, a device **504** for discharging a high pressure fluid into the wellbore **510** and a pair of packers **506a** and **506b** spaced apart on the service tool **500** to seal a zone of interest **518** in the wellbore **510**. To test the integrity of the seal **514**, the service tool **500** is positioned adjacent to a juncture **515** to provide an

image of the juncture **515**, which image is utilized to position the tool **500** such that the upper packer **506a** is above the juncture **515** and the lower packer **506b** is below the juncture **515**. The packers **506a-506b** are then set as shown in **FIG. 11** to seal the space **518** enclosed by the seal **514**, the upper packer **506a** and the lower packer **506b**. Pressurized fluid is then discharged from the device **504** into the space **518** via openings **504a**. The pressure drop, if any, in the space **518** is measured over a predetermined time period, which provides an indication of the seal integrity.

**FIG. 12** shows a configuration of a service tool **520** for use in testing a production zone or reservoir **525**. This configuration is substantially similar to the tool configuration shown in **FIG. 11**. **FIG. 12** shows a cased hole **540** having a production zone **539**. The casing **530** has a plurality of perforations **532** through which fluids from the reservoir **525** enter into the casing **530** at zone **539**. Periodic testing of production zones is commonly performed during the life of such production zones to determine the fluid flow from each zone or a portion thereof, to build and update reservoir models and to estimate the future production from such reservoirs. To test a production zone, such as zone **539**, the tool **520** images the perforated zone **542** (work site). The image is utilized, among other things, to position the tool **520** adjacent to the perforations **532**. The packers **526a** and **526b** are set in the casing **530** to seal the zone **539** between the packers **526a-526b**. A testing device **524** is then

utilized to perform desired testing. The testing device **524** shown has a flow control valve **524a** to control the fluid flow from the reservoir into the tool **530**. The received fluid may be collected in chambers **527** for further analysis or discharged into the wellbore uphole of the upper packer **526a**. The testing device **524** also may include temperature sensors, pressure sensors and may include devices to determine chemical and/or physical properties of the fluids, including specific gravity, oil, gas and water content in the formation fluid. To determine pressure and temperature build up, commonly performed for reservoir modeling, the valve **524** is closed and required measurements are made over a predetermined time period. Any other type of testing device may also be employed in addition to or as an alternative to the device **424**. The image obtained of the perforated zone **539** allows an operator to position the tool **530** precisely adjacent to the desired perforations **532**. The packers **526a** and **526b** may be made slidable over the tool **530** so that the length of the zone **539** may be adjusted downhole.

It will be obvious that **FIGS. 11** and **12** show specific examples in which the service tool of the present invention can be utilized to image a work site in a wellbore and then perform testing (end work) during a single trip in the wellbore. Any other suitable testing device may be utilized for the purposes of this invention.

FIGS. 13 and 14 show examples of the service tool of the present invention for performing remedial work in preexisting wellbores. FIG. 13 shows the service tool 550 conveyed in a cased wellbore 555 lined with a casing 556. The casing 556 has a plurality of perforations 558 adjacent to a reservoir 560. The service tool 550 includes a suitable image device 564 and a device or unit 566 for injecting fluids under pressure into the wellbore 555. The remedial work in the wellbore 555 may include injecting a fluid (water, sand, glass, chemicals or mixture of water and additives, etc.) under pressure through the perforations 558 to increase the flow of formation fluids from the reservoir 560 into the wellbore 555. To perform such a remedial work, the service tool 550 is positioned in the wellbore 555 to obtain images of the perforated zone 568. The images are utilized to reposition the tool, if necessary. Packers 570a and 570b are set in place to isolate the desired zone of interest or the work site 568. The desired fluid is then injected into the zone 568 by the device 566 via control valves 566a. The desired fluid may be injected via tubing 557 from the surface. The flow from each of the control valves 566a is preferably independently controlled by a downhole control unit 571. The above-described system is equally applicable for open hole fracturing applications.

The service tool 550 shown in FIG. 13 may also contain a test device, such as the test device 572, similar to the test device 534 shown in FIG. 11 to perform testing of the zone 568 to determine the effectiveness of the work

performed. The service tool **550** shown in **FIG. 13** thus may be utilized to image a work site (production zone **568**), perform a work (remedial work) at the work site, and then determine the effectiveness of the work performed during a single trip in the wellbore.

During the life of a wellbore, it is sometimes desired or even required to seal off a production zone or a portion thereof for reasons such as the zone is producing excessive amounts of water and is impeding the flow of hydrocarbons from other production zones in the same wellbore. **FIG. 14** shows a configuration of a service tool **580** of the present invention for sealing a production zone **599** or a portion thereof by cementing the zone **599** and then confirming the integrity of the seal. **FIG. 14** shows a service tool **580** conveyed in a cased wellbore **581** lined with a casing **582**. The casing **582** has a plurality of perforations **584** adjacent to a reservoir **585**. The service tool **580** includes a suitable image device **586** and a device or unit **588** for injecting cement slurry under pressure into the wellbore **581**. The remedial work in the wellbore **581** may include closing off a single perforation **584a** or the zone **599** having a number of perforations **584**. To close off the zone **599**, the tool **580** is positioned in the wellbore **581** to obtain images of the perforated zone **599**. The images are utilized to reposition the tool **580**, if necessary, and packers **596a** and **596b** are set in place to isolate the desired zone of interest or the work site of interest **599**. The cement is then injected from the cement device

588 into the zone 599 via a control valve 592b to seal the intended zone 599. The tool 580 is then retrieved. To cement a single perforation, such as perforation 584a, a flexible cup 590 on the outside of the tool 580 is urged against the perforation 584a. Cement or any other desired fluid is then controllably discharged from an opening 592a to close the perforation 584a. The tool 580 may also include a testing device 594 to test the integrity of cementing work. The device 594 may be a flow measuring device to determine if any fluid is flowing out of the cemented zone. Pressure and temperature measuring devices and resistivity measuring devices may also be utilized as test devices. Additionally, the image device 586 may be utilized to obtain secondary images of the cemented work site to determine the effectiveness of the work performed. It should be noted that the term cement is used to generally mean hardening materials, including cement slurry, epoxies and any other suitable material. In some cases, it is desirable to intentionally damage a formation or zone to seal unwanted production of formation fluids. The above-described method may also be utilized for such applications.

FIGS. 15 and 16 show examples of service tools of the present invention for performing fishing operations preexisting wellbores. FIG. 15 shows a service tool 630 conveyed in a wellbore 632 by a tubing 633. The service tool 630 includes a suitable image device 635 having a retractable tactile sensor for imaging an object, such as a fish 640 stuck in the wellbore 632. The tactile

image device **635** includes a retractable probe **637**, which has a tip **639** that can scan the entire inside of the wellbore **632**. The probe tip **639** attached to an arm **641** which can move radially and axially around a rotary joint **638**. The joint **638** can move axially as shown by the dotted lines **643**, thereby providing sufficient numbers of degrees of freedom to the probe tip **639** to scan the wellbore **632**. The service tool **630** includes a suitable fishing device for engaging the fish **640** and other devices, sensors, control circuits and telemetry, collectively designated by numeral **645**. To retrieve the fish **640** from the wellbore **632**, the service tool **630** is positioned above the fish **640**. The imaging device **635** senses the location and profile of the fish **640**, which is communicated to the surface. The tool **630** is then repositioned, the fishing device **644** is activated to engage the fish **640**. Any other suitable imaging device may be utilized for imaging the fish **640**. Also any suitable fishing device may be utilized for the purpose of this invention. For example, the fishing device may be the type that grabs the fish from the outside or the inside of the fish **640**. It may be a spear type or an over-shot type device as described in U.S. Patent No. 5,242,201, which is incorporated herein by reference. The fishing tool **635** may drill into the fish **640** to securely engage the fish **640**. The fish **640** is retrieved by retrieving the tool **630**. It should be obvious that the tactile imaging device **635** may include more than one probes and that such imaging devices may be utilized in any of the service tools made according to this invention.

FIG. 16 shows the use of a service tool 650 conveyed in a wellbore 652 by a tubing 653. The service tool 650 includes a suitable imaging device 660, including an ultrasonic and tactile device. In the example of FIG. 16 a fish 666 is shown stuck in a wash-out area 654 of the wellbore 652. To retrieve the fish 666, the tool 650 is positioned adjacent to the fish 666 to image the 666 fish by the imaging device 660. The tool 650 may include a one or more knuckle devices 672 that can be activated from the surface or downhole control circuits 670 to position the image device 660 and a fishing device 664 in the wash-out region 654. After the image is taken, the fishing device 664 is repositioned to engage the fish 666. The fish 666 may be moved from the wash-out region 654 by reactivating the knuckle joints 672. The fish 666 is retrieved by retrieving the tool 650. It should be noted that any suitable imaging and fishing devices may be utilized for the purpose of this application. The fishing tools of this invention preferably have degrees of freedom of movement that are sufficient to position the tool to retrieve the fish at any place in the wellbore.

Thus far selected examples of the downhole service tool have been described above to illustrate the concepts of the present invention. It will, however, be understood that many other end work devices and imaging devices can be utilized to image an object and work site in a wellbore and to perform a desired operation at the work site without requiring retrieving the service tool

according to the concepts of this invention. For example, the service tool **200** (FIG. 1) of the present invention may be utilized to locate a weak point in the well casing, such as a crack or a pit, and perform welding. The service tool **200** may be utilized to perform swaging operations downhole or to inject polymers into the wellbore. Yet, in certain other applications, it is desirable to confirm the engagement of a tool conveyed from the surface to downhole device prior to performing an operation with such tool. The service tool of the present invention may include an engagement device and a sensor for generating signals that differ when the tool is engaged with the downhole device and when it fully or properly engaged. The service tool may include without limitation any desired engagement device, including a collet type device, a screw type device, a latching device that is designed to latch into or onto a receptacle associated with the downhole device, a cone type device, a device that is designed to mate with a matching profile in the downhole device, or a collet or a pressure activated device. To perform the desired operation, the service tool is placed at a desired location in the wellbore and the sensor is activated to provide the tool response. The tool is engaged with the downhole device. The sensor continues to provide signals responsive to the engagement process. The response signature is utilized to confirm the engagement of the tool device with the downhole device.

Additionally, the service tool **200** may incorporate one or more robotics

devices that can remove a member or a sensor, install a sensor or a device, such as a fluid control valve, remove a liner, interchange parts, replace power sources, such as batteries, turbines, etc., inflate a device, manipulate a device or part downhole from its current position to a new position, such as a sliding sleeve from an open position to a closed position or vice versa, and perform any other desired function. The image device in the service tool is preferably utilized to locate the part to be replaced, installed or manipulated.

It is often desirable to measure selected wellbore and formation parameters either prior to or after performing an end work. Frequently, such information is obtained by logging the wellbore prior to performing the end work, which typically requires an extra trip downhole. The service tool of the present invention, such as tool **200** shown in **FIG. 1** and other tools shown in **FIGS. 2-16** may include one or more logging devices or sensors. For example, for the work to be performed in cased holes, such as shown in **FIGS. 10a-14,** a collar locator may be incorporated in the service tool **200** to log the depth of the tool **200** while tripping downhole. Collar locators provide relatively precise measurements of the wellbore depth and can be utilized to correlate depth measurement made from surface instruments, such as wheel type devices. The collar locator depth measurements can be utilized to position and locate the imaging and end work devices of the tool **200** in the wellbore. Also, casing inspection devices, such as eddy current devices or magnetic devices may be

utilized to determine the condition of the casing, such as pits and cracks. Similarly, a device to determine the cement bond between the casing and the formation may be incorporated to obtain a cement bond log during tripping downhole. Information about the cement bond quality and the casing condition are especially useful for wellbores which have been in production for a relatively long time period or wells which produce high amounts of sour crude oil or gas. Additionally, resistivity measurement devices may be utilized to determine the presence of water in the wellbore or to obtain a log of the formation resistivity. Similarly gamma ray devices may be utilized measure background radiation. Other formation evaluation sensors may also be utilized to provide corresponding logs while tripping into or out of the wellbore.

The description thus far substantially relates to a service tool which utilizes an image sensor and an end work device to image a work site in a wellbore and perform a selected end work. As described earlier, the service tool of the present invention also provides confirmation about the quality and effectiveness of the end work performed downhole during the same trip. The general operation of the above-described tools is described by way of an example of a functional block diagram for use with the system of **FIG. 1**. Such methods and operations are equally applicable to the other downhole service tools made according to the present invention. Such operations will now be described while referring to **FIG. 17**.

The downhole section of the control circuit **900** preferably includes a microprocessor-based downhole control circuit **910**. The control circuit **910** determines the position and orientation of the tool as shown in box **912**. A circuit **915** controls the operation of the downhole tool. The control circuit **910** also controls the end work devices, such as cutting tool **914a** and any other end work devices, generally designated herein by numeral **914n**. During operations, the control circuit **910** receives information from other downhole devices and sensors, such as a depth indicator **918** and orientation devices, such as accelerometers and gyroscopes. The control unit **900** communicates with the surface control unit **970** via the downhole telemetry **939** and via a data or communication link **939a**. The control circuit **910** also preferably controls the operation of the downhole devices, such as the power unit **934**, stabilizers and other desired downhole devices (not shown). The downhole control circuit **910** includes a memory **920** for storing therein data and programmed instructions. The surface control unit **970** preferably includes a computer **930**, which manipulates data, a recorder **932** for recording images and other data and an input device **934**, such as a keyboard or a touch screen for inputting instructions and for displaying information on the monitor **972**. The surface control unit **970** and the downhole tool communicate with each other via a suitable two-way telemetry system.

While the foregoing disclosure is directed to the preferred embodiments

of the invention, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

**<u>WHAT IS CLAIMED IS:</u>**

1. A downhole tool for imaging a work site within a pre-existing wellbore and performing a tool operation at the work site during a single trip of the tool in the wellbore, the tool comprising;

   (a) an imaging device in the downhole tool for imaging the work site; and

   (c) a work device in the downhole tool for performing the tool operation at the work site, whereby the downhole tool obtains the image of the work site and performs the tool operation at the work site during a single trip of the downhole tool into the wellbore.

2. The downhole tool of claim 1, wherein the imaging device is selected from the group comprising a camera for optical viewing, an acoustic device, an ultrasonic device, an infra-red device, an RF device, a microwave device, a contacting device, a tactile device and a fiber optic device.

3. The downhole tool of claim 1, wherein the wellbore is a cased wellbore.

4. The downhole tool of claim 1, wherein the imaging device is a contacting device comprising a series of projections extending from the downhole tool that can engage with the wellbore and objects in the wellbore.

5. The downhole tool of claim 1, wherein the transmitter is selected from the group comprising an electromagnetic transmitter, a fluid acoustic transmitter, a tubular fluid transmitter, a mud-pulse transmitter, a fibre optics transmitter and a conductor wire transmitter.

6. The downhole tool of claim 1, wherein the end work device is selected from the group comprising a fishing tool to engage with a fish downhole, a whipstock, a diverter, a re-entry tool, an anchor, a packer, a seal, an inflatable packer, a plug, a perforating tool, a fluid stimulation tool, an acidizing tool, a fluid fracturing tool, a milling tool, a cutting tool, a patch tool, a drilling tool, a cladding tool, a welding tool, a deforming tool, a sealing tool, a cleaning tool, a device for installing a device in the wellbore; a device for removing a device downhole; a testing device for performing a test in the wellbore; an inspection device; and a tool for engaging with a downhole object to perform a desired operation.

7. The downhole tool of claim 1 further comprising a computer having at least one processor for controlling the operation of the end work device.

8. The downhole tool of claim 1, wherein the end work device is movable radially and longitudinally relative to the wellbore.

9. The downhole tool of claim 1 further comprising a memory positioned for recording data from the sensor for data retrieval when the service tool is brought back to the surface.

10. The downhole tool of claim 1 further comprising a memory pre-programmed with a work site data model for correlating data generated downhole with pre-programmed work site data to facilitate the identification of the work site.

11. The downhole tool of claim 10, wherein the transmitter generates signals for transmission to the surface representative of the data correlation and, thus, of the work site data generated downhole.

12. The oilfield tool of claim 11, wherein the transmitter communicates with other equipment positioned downhole in the wellbore.

13. The downhole tool of claim 1 further comprising a receiver associated with the downhole tool for receiving signals sent from the surface to the downhole tool, with the receiver communicating with a processor in the downhole tool.

14. The downhole tool of claim 1 further comprising a formation evaluation

sensor adjacent the lower end of the tubing.

15. The downhole tool of claim 1 further comprising at least one sensor for determining an operating condition of the downhole tool during drilling of the wellbore, said at least one sensor selected from the group comprising temperature, pressure, fluid flow, tool orientation, pull force, gripping force, tool centerline position, tool configuration, inclination, and acceleration.

16. The downhole tool of claim 1, wherein the imaging device detects objects positioned downhole of the tool.

17. The downhole tool of claim 1, wherein the imaging device is an ultrasonic device positioned in the downhole tool to provide images of the work site located downhole of the downhole tool.

18. The downhole tool of claim 17, wherein the ultrasonic device includes a at least one transmitter for transmitting signals to the work site downhole of the downhole tool and a receiver for receiving signals reflected by the work site.

19. The downhole service tool of claim 18, wherein the imaging device operates the transmitter by sweeping a preselected frequency range to obtain an effective operating frequency and continues to operate the transmitter at

such effective frequency to generate data representative of attributes of the work site.

20. The downhole tool of claim 1, wherein the imaging device is beam steered to generates data representative of the properties of the work site.

21. The downhole tool of claim 1, wherein the imaging device includes a sensor that is rotated to generate data representative of the properties of the work site.

22. The downhole tool of claim 1, wherein the end work device is a cutting device that performs cutting with a high pressure fluid.

23. The downhole tool of claim 1, wherein the end work device is a reentry device that includes an orienting device that can be oriented to enter into a lateral wellbore intersecting the wellbore.

24. The downhole tool of claim 23, wherein the orienting device is selected from a group of devices consisting of a knuckle joint, a flexible joint that is operated by a control circuit in the downhole tool, a flexible joint that is remotely operable, and a deflection device that reorients the downhole when said deflection device is urged against the wellbore.

25. The downhole tool of claim 1 further comprising two spaced apart isolators, said isolators isolating a zone of interest in the wellbore.

26. The downhole tool of claim 25 further comprising a device for injecting fluid enterpriser into the zone of interest to perform testing of the zone of interest.

27. The downhole tool of claim 25, wherein the isolated zone is selected from the group consisting of a perforated zone, and juncture between the wellbore and a lateral wellbore.

28. The downhole tool of claim 1, wherein the imaging device is a tactile device having al least one probe that extends from the downhole tool to make contact with the work site to provide signals representative of the physical attributes of the work site.

29. A method of imaging a location constituting a work site of interest at which a tool operation is to be performed in a pre-existing wellbore and performing a work at the work site during a single trip, comprising:

(a) providing a tubing extending from the surface down into the wellbore, a sensor adjacent the lower end of the tubing for sensing properties associated with the work site and generating data

representative of the work site, a transmitter for receiving the data and transmitting signals representative of the data to the surface and an end work device adjacent the lower end of the tubing for performing the desired tool operation;

(b) extending the tubing into the wellbore toward the work site;

(c) sensing properties associated with the work site downhole;

(d) generating data representative of the image of the work site;

(e) transmitting signals representative of the data to the surface; and

(f) performing the desired tool operation at the work site location before removing the tubing from the wellbore.

30. A method of imaging a work site and performing an end work at the work site in a pre-existing wellbore during a single trip into the wellbore, comprising:

(a) conveying a downhole tool into the wellbore, said downhole tool having an imaging device for imaging a work site in the wellbore, a device for isolating the work site, and an end work device for performing a desired work at he work site;

(b) isolating the work site;

(c) imaging the work site by the imaging device; and

(d) operating the end work device to perform a desired operation at the work site.

31. A method of imaging a location constituting a work site of interest in a preexisting wellbore at which a desired operation is to be performed without removing the tool from the wellbore, comprising:

(a) positioning a downhole tool adjacent the work site, said downhole tool having an imaging device for sensing properties associated with the work site and generating data representative of the work site, a transmitter for receiving the data and transmitting signals representative of the data to the surface and an end work device for performing the desired tool operation;

(b) generating data representative of the work site and transmitting signals representative of the data to the surface by the transmitter; and

(c) performing the desired tool operation at the work site location before removing the tool from the wellbore.

32. A downhole service tool; comprising;

(a) a packer adjacent a lower end of the tool, said packer having a packing member on a housing that forms a seal between the housing and a work site in a preexisting wellbore when a fluid is injected into the packing member; and

(b) a sensor uphole of the packer for providing data representative of an image the work site when the downhole tool is conveyed into

the wellbore for setting the packer in the wellbore.

33. A downhole oilfield service tool for imaging a work site in a wellbore and for performing a desired operation at the work site without requiring retrieving the service tool from the wellbore prior to performing the desired operation, said service tool conveyable into the wellbore by a tubing extending from a surface location toward and adjacent the work site, comprising:

(a) an ultrasonic sensor adjacent a lower end of the tubing for providing an image of the work site and generating data representative said image;

(b) a transmitter associated with the service tool for receiving the data generated by the sensor and transmitting signals representative of said data to the surface; and

a milling tool adjacent the lower end of the tubing for performing a cutting operation at the work site based at least partially upon said data without retrieving the service tool from the wellbore prior to performing the desired operation.

34. A downhole service tool for entering into a branch wellbore from a juncture at a main wellbore to perform an end work at a work site in the branch wellbore during a single trip into the main wellbore, comprising:

(a) a sensor adapted to obtain data for an image of the juncture;

(b) a control circuit in the service tool for receiving the data from the sensor and transmitting signals representative of said data to the surface to obtain the image of the juncture; and

a tool orientation device in the service tool, said device adapted to be operated downhole by the control circuit, to cause the service tool to enter the branch wellbore; and

an end work device for performing the desired end work at the desired work site in the branch wellbore, whereby the service tool can locate the juncture, enter into the branch wellbore from the main wellbore and perform the desired operation at the work site in a single trip.

35. The downhole service tool of claim 34, wherein the tool orientation device is selected from a group comprising, a knuckle joint that is controlled from a command from the surface, a knuckle joint that is controlled downhole, a plurality of independently adjustable pads, and a member that extends outward from the service tool to urge against the wellbore to cause the service tool to move transverse to the wellbore axis.

36. A downhole service tool for imaging a selected work site in a wellbore and performing a welding operation at the selected work site in a wellbore during a single trip, comprising:

(a) a sensor adapted to obtain data to image the work site;

(b) a control circuit in the service tool for receiving the data from the sensor and transmitting signals representative of said data to the surface to obtain the image of work site; and

a welding device in the service tool, said welding device adapted to be operated downhole by the control circuit to perform the welding operation at the work site during the single trip.

37. The downhole service tool of claim 36, wherein the selected work site is selected from a group comprising a joint between casing in a main wellbore and a branch wellbore formed from the main wellbore and a packer.

38. A downhole oilfield service tool conveyable into a wellbore for imaging a location constituting a work site of interest downhole and performing a testing operation at the work site during a single trip of the tool in the wellbore, the tool comprising;

(a) a sensor adjacent for sensing properties associated with the desired work site in the wellbore and generating data representative of the work site;

(b) a transmitter for receiving the data from the sensor and transmitting signals representative of said data to the surface; and

a pair of spaced apart seals on the service tool to seal at least a

portion of the work site of interest between the pair of seals; and

(d) a testing device in the tool to perform a selected test in the sealed work site, during the single trip.

39. The downhole service tool of claim 38, wherein the selected work site is a perforated zone.

40. The downhole service tool of claim 39, wherein the testing device performs a test selected from the group comprising pressure test of a sealed region, pressure build-up over a time period, temperature test, temperature build-up over a time period, reservoir analysis, formation evaluation, resistivity of formation fluids, sample collection, formation fluid analysis, and hydrocarbon content of formation fluids.

41. A downhole oilfield service tool conveyable into a wellbore for imaging a location constituting a work site of interest downhole and performing a workover operation at the work site during a single trip of the tool in the wellbore, the tool comprising;

(a) a sensor adjacent for sensing properties associated with the desired work site in the wellbore and generating data representative of the work site;

(b) a transmitter for receiving the data from the sensor and

transmitting signals representative of said data to the surface; and a pair of spaced apart seals on the service tool to seal at least a portion of the work site of interest between the pair of seals; and

(d) a device for injecting a pressurized fluid into the sealed portion of the work site to perform the workover operation, during the single trip.

42. The downhole service tool of claim 41, wherein the work site of interest is a perforated region and the sealed portion includes at least one perforation.

42. The downhole service tool of claim 41, wherein the fluid is selected from a group comprising cement slurry, polymer, water, steam, chemicals, and acidizing fluids.

43. The downhole service tool of claim 41, wherein the workover operation is selected from the group comprising injecting fluids into a perforated zone to improve hydrocarbon production, sealing of a zone to prevent production of fluids therefrom, cementing, fracturing, and cleaning.

44. A downhole visual imaging tool for obtaining an image of a predetermined area of interest within a wellbore having substantially non-transparent fluid therein, the imaging tool comprising:

(a) a tool body conveyable into the wellbore;

(b) a seal for blocking fluid communication to the area of interest , the tool body having a device for providing a fluid seal between the imaging tool and the work site when the imaging tool is placed a predetermined distance from the work site;

a fluid injection system for displacing the non-transparent fluid between the imaging tool and the work site with a substantially transparent fluid; and

(d) a camera associated with the imaging tool for taking an image of the work site.

45. The imaging tool of claim 44, wherein the tool body is conveyable into the wellbore by a conveying device selected from a group consisting of a wireline, a tubing and a traction device that can move the downhole imaging tool through the wellbore.

46. The imaging tool of claim 44, wherein the camera is adapted to be remotely oriented in a desired direction to take an image of the work site.

47. The imaging tool of claim 44 further having a control unit at the surface for receiving data from the camera and for displaying the image of the work site.

48. The imaging tool of claim 47, wherein the control unit controls the operation of the fluid injection system.

49. The imaging tool of claim 44 further having a control circuit within the imaging tool for automatically controlling the operation of the fluid injection system and for operating the camera to obtain the desired image of the work site according to programmed instructions provided to the control circuit.

50. The imaging tool of claim 44, wherein the imaging tool provides a multi-dimensional view of the work site from data provided by the camera.

51. The imaging tool of claim 44, wherein the fluid injection system comprises:

(I) a source of substantially transparent fluid; and

(ii) a fluid transfer mechanism for displacing the at least a portion of the substantially non-transparent fluid with the substantially transparent fluid wellbore.

52. The imaging tool of claim 51 further having a fluid communication line coupled to the fluid chamber for retrieving the substantially transparent fluid from the wellbore into the fluid chamber.

53. The imaging tool of claim 52, wherein the fluid transfer mechanism is coupled to the fluid communication line for causing the substantially transparent fluid to flow from the wellbore into the fluid chamber.

54. The imaging tool of claim 44, wherein the device for providing the seal is a packer.

55. A method for imaging a work site of interest located within a wellbore below a surface location, the wellbore containing a substantially non-transparent fluid therein, said method comprising:

(a) setting a fluid seal a predetermined distance above the work site;

(b) displacing the substantially non-transparent fluid between the work site and the seal with a substantially transparent fluid; and taking an image of the work site with a camera placed between the seal and the work site.

56. A method for imaging a work site of interest located within a wellbore containing a substantially non-transparent fluid therein, said method comprising:

(a) conveying an imaging tool within the wellbore to a location above the work site;

(b) isolating utilizing at least one seal the work site;

displacing the substantially non-transparent fluid in the work site with a substantially transparent fluid; and

(d) obtaining an image of the work site with the imaging tool.

57. The method of claim 56 further having a circuit within the imaging tool for communicating the image to a surface location.

58. An imaging tool for obtaining an image of a work site of interest within a wellbore, comprising:

(a) a tool body conveyable into the wellbore;

(b) a flexible inflatable device on the tool body having a plurality of spaced sensors arranged at a plurality of predetermined surface locations on the inflatable flexible device, each such sensor providing a signal in response to deformation of the surface locations of the flexible inflatable device at which such sensor is placed relative to a predetermined norm for such sensor; and

a computer, said computer receiving signals from the sensors in the plurality of sensors when the inflatable flexible device is inflated and urged against the work site and in response thereto providing an image of the work site.

59. The imaging tool of claim 58, wherein the computer is located at a

surface location.

60. The imaging tool of claim 58, wherein the computer is located within the imaging tool for computing the image of the work site downhole during operation of the imaging tool.

61. The imaging tool of claim 58, wherein the imaging tool transmits data to the computer representative of an image of the work site determined from the sensors in the plurality of sensors.

62. The imaging tool of claim 58 further having a fluid injection system for injecting a fluid into the inflatable flexible device.

63. A downhole oilfield service tool for imaging a work site in a wellbore and for performing a desired operation at the work site during a single trip of the service tool conveyed into the wellbore by a tubing extending from a surface location toward and adjacent to the work site, comprising:

(a) an imaging device adjacent a lower end of the tubing for providing an image of the work site; and

(b) an end work device adjacent the lower end of the tubing for performing the desired operation at the work site based at least partially upon the image of the work site during the single trip of

the service tool in the wellbore.

FIG. 1

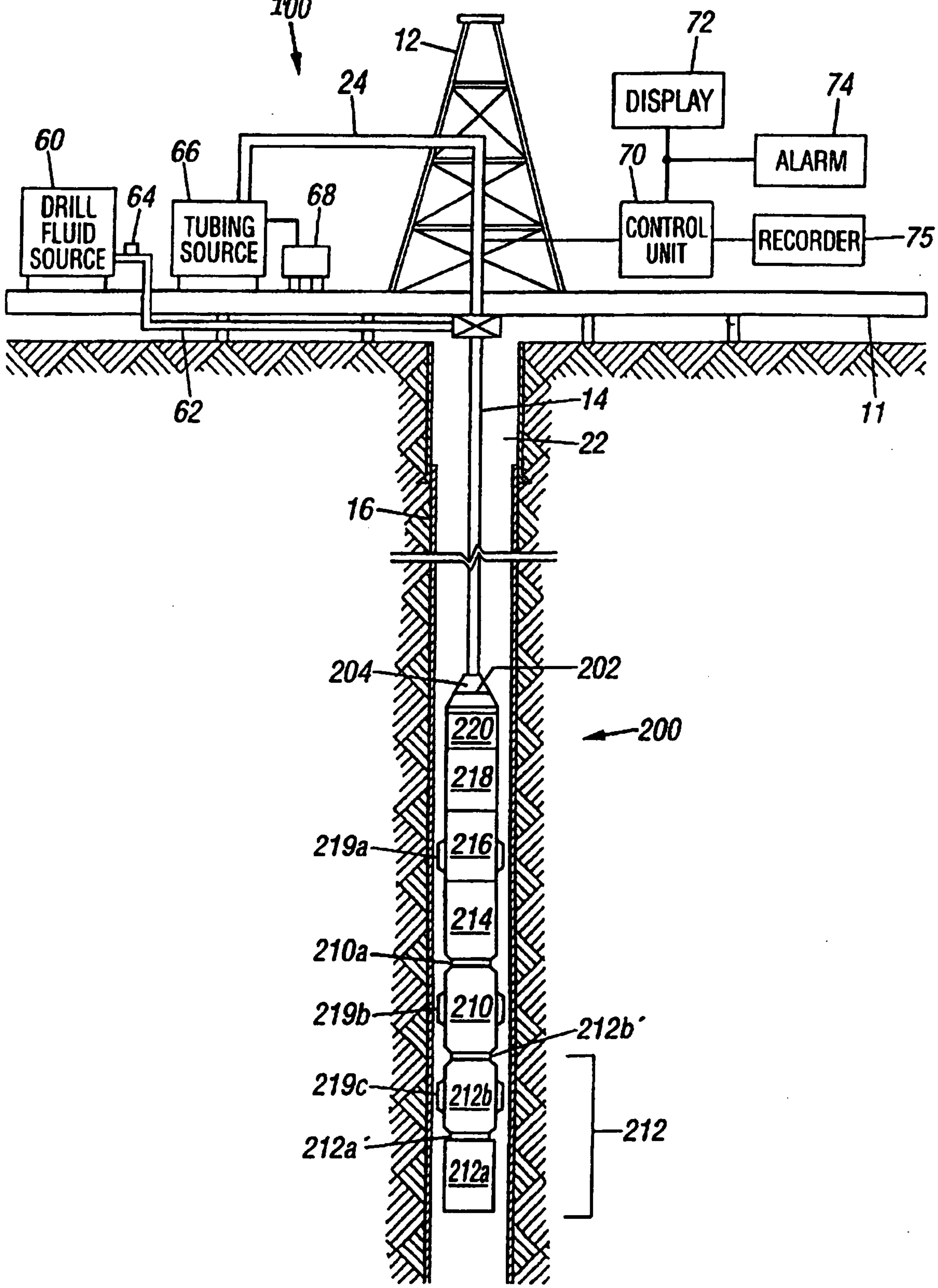

100
12
24
72
DISPLAY
74
ALARM
60
66
70
64
68
DRILL FLUID SOURCE
TUBING SOURCE
CONTROL UNIT
RECORDER
75
62
14
11
22
16
204
202
220
200
218
219a
216
214
210a
210
219b
212b'
219c
212b
212
212a'
212a

FIG. 2

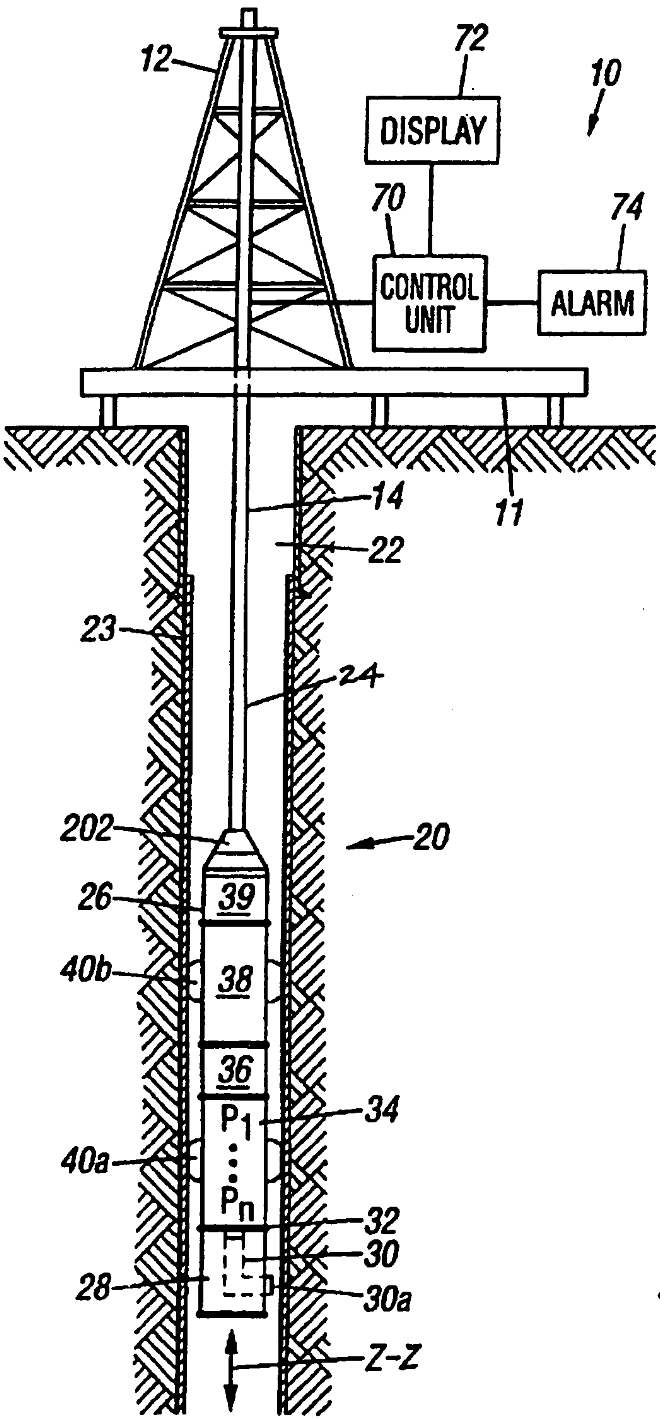

12
72
10
DISPLAY
70
74
CONTROL UNIT
ALARM
14
11
22
23
24
202
20
26
39
40b
38
36
34
P1
40a
Pn
32
30
28
30a
Z-Z

FIG. 1A

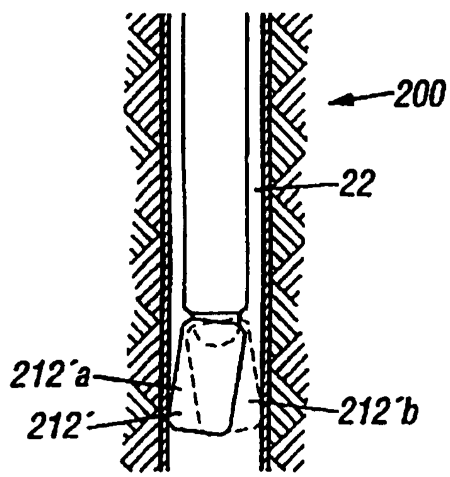

200
22
212'a
212'
212'b

FIG. 2A

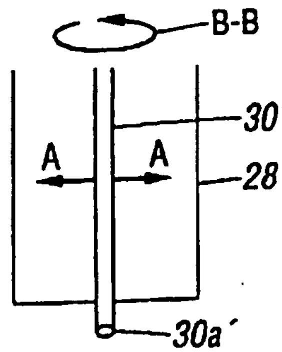



FIG. 3

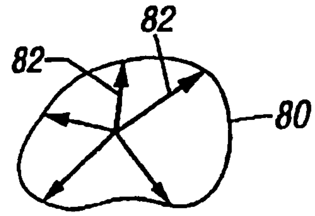



FIG. 4

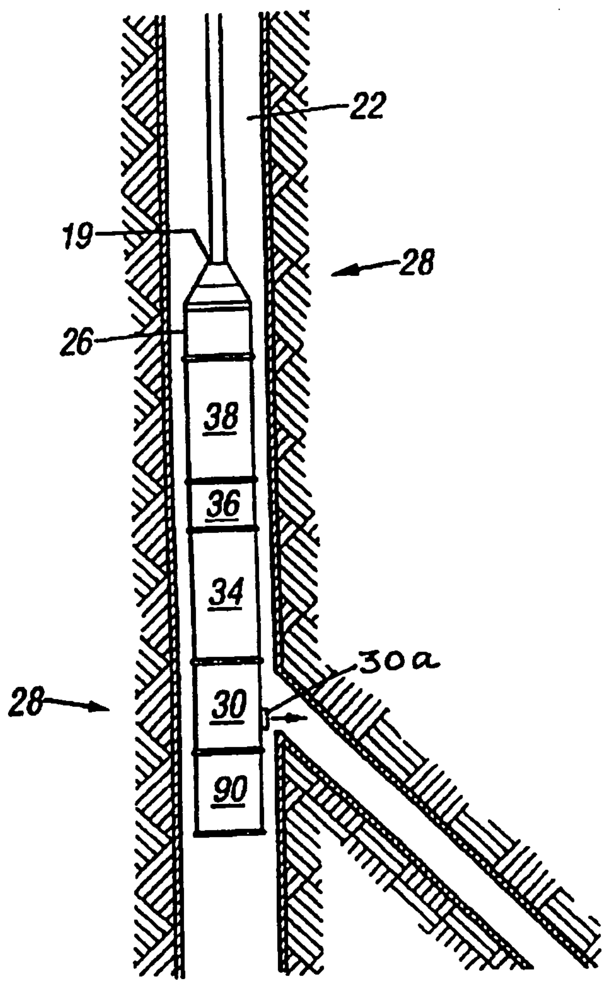



FIG. 2B

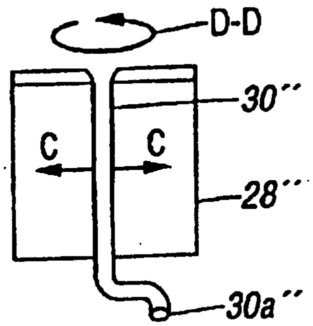



FIG. 2C

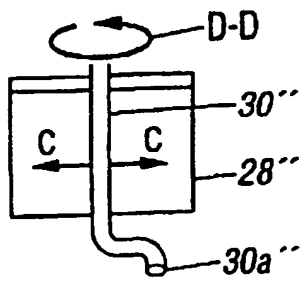


FIG. 5A

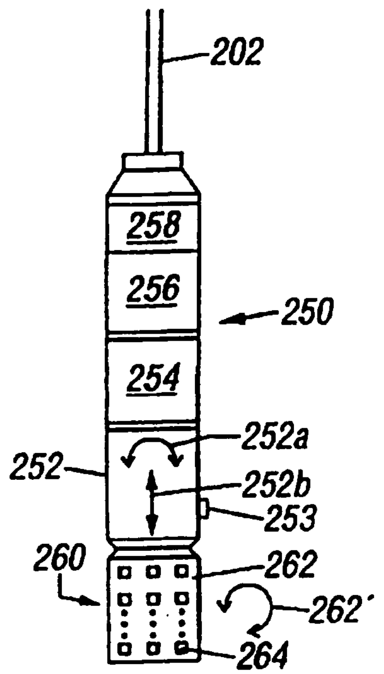



FIG. 5B

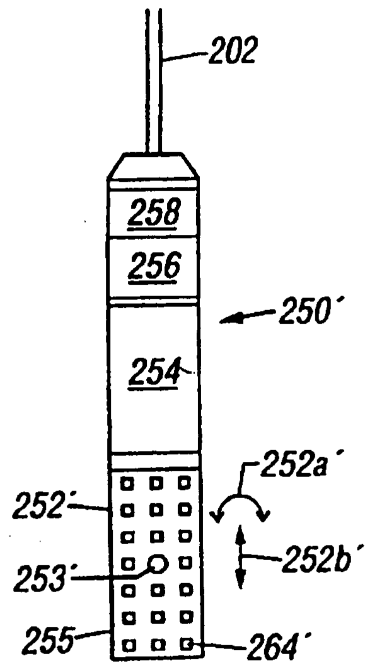



FIG. 5C

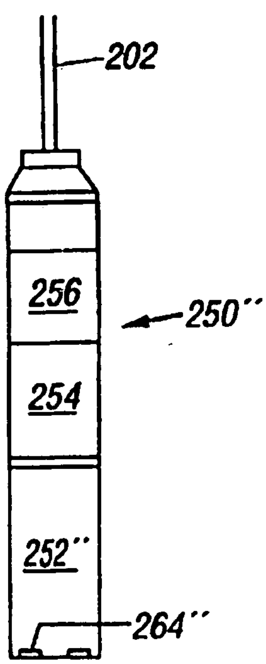
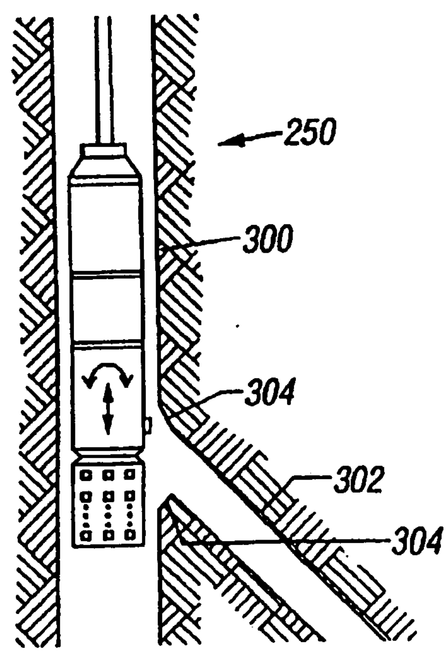


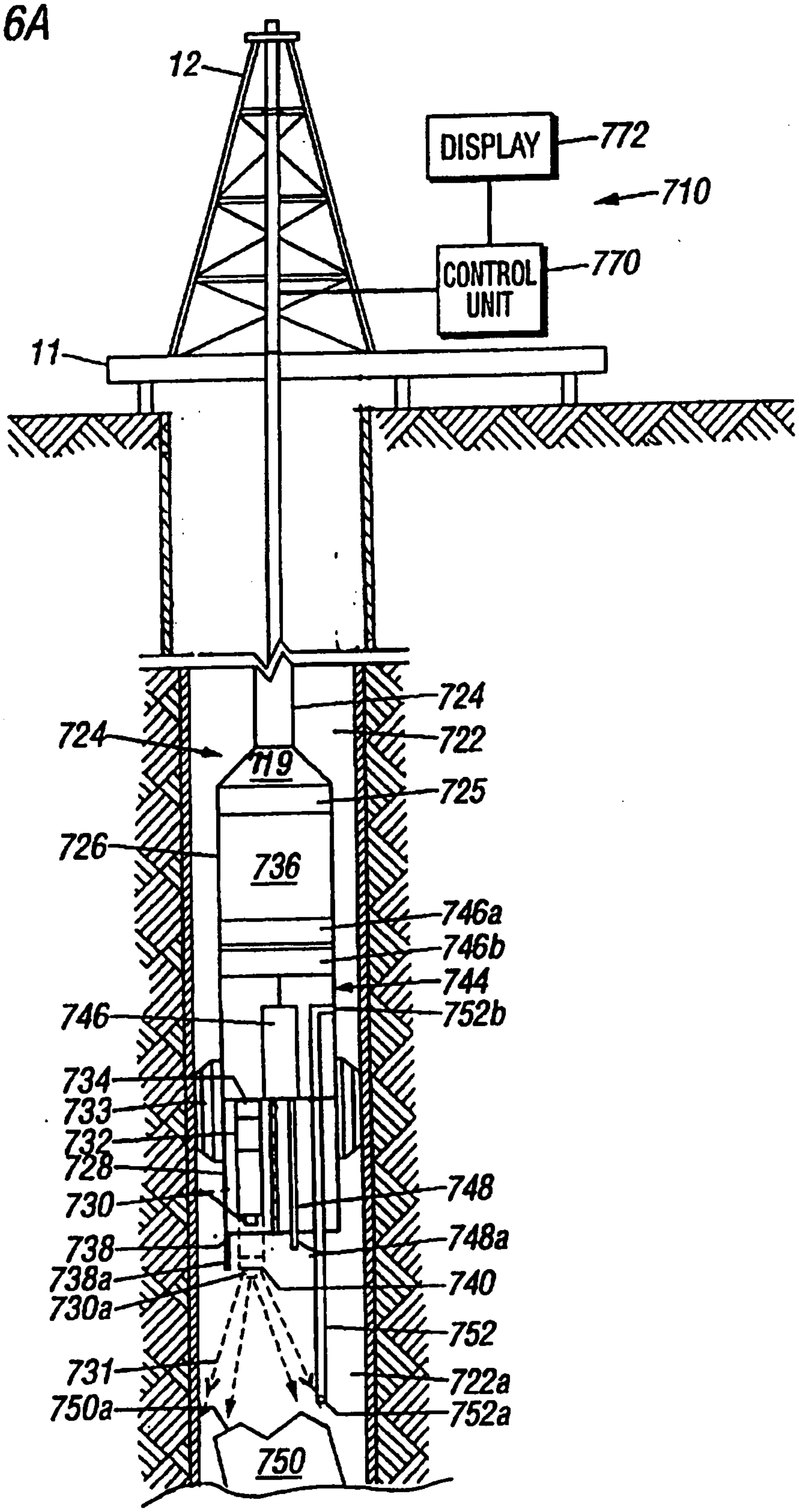

FIG. 5D






SUBSTITUTE SHEET (RULE 26)

FIG. 6A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DISPLAY
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CONTROL UNIT
770
11
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726
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746a
746b
744
746
752b
734
733
732
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748a
738
738a
730a
740
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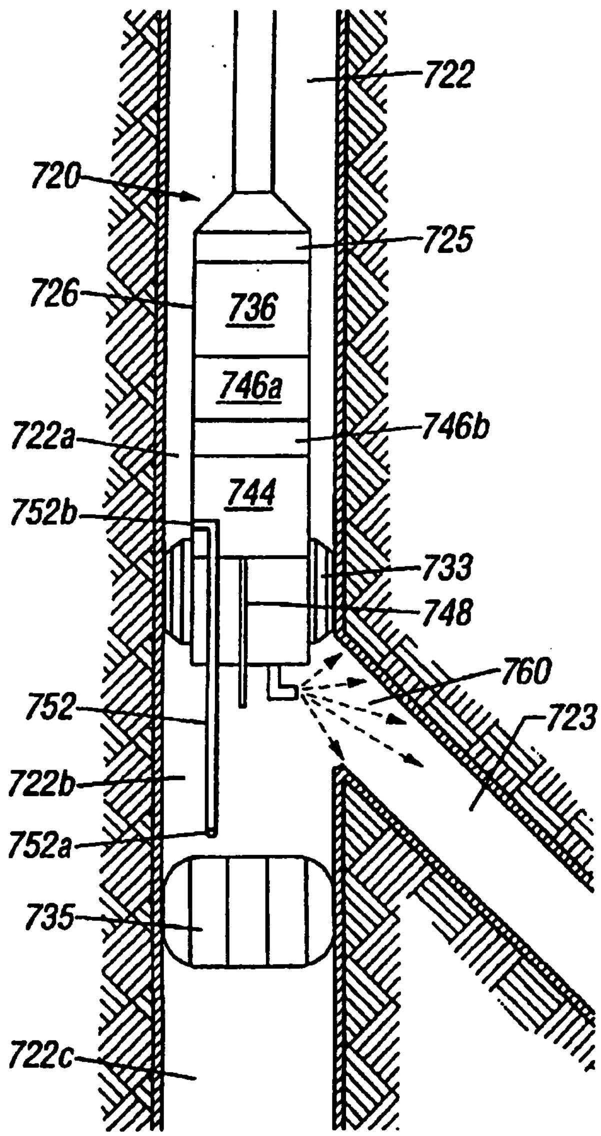
731
722a
750a
752a
750

FIG. 6B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746a
722a
746b
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752b
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748
760
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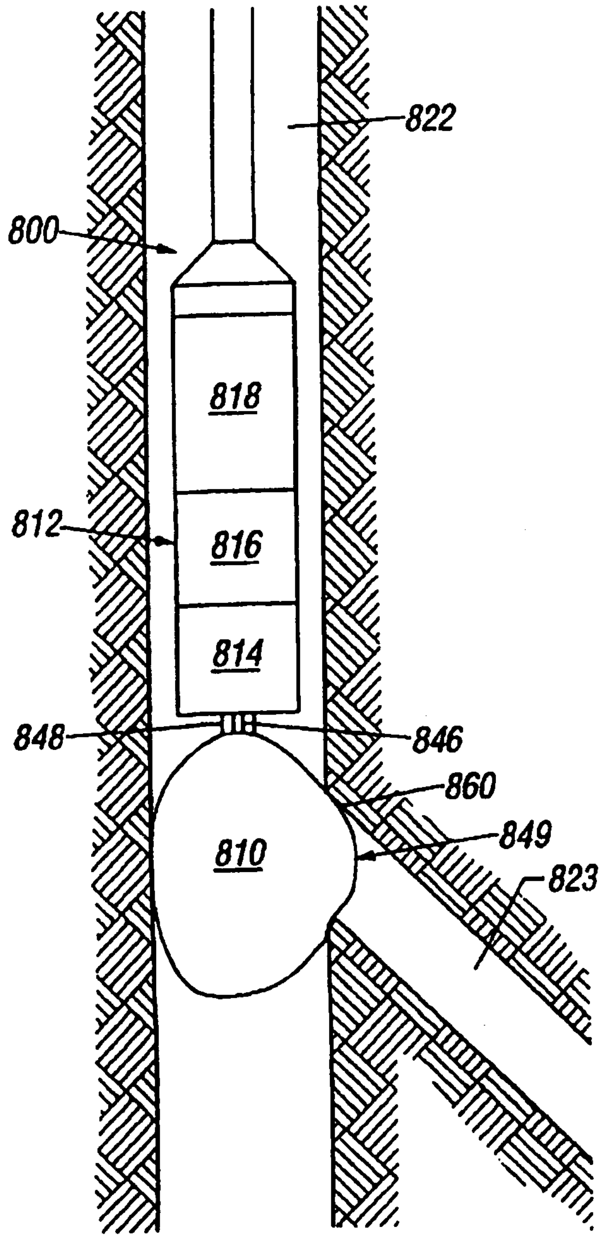
752
722b
752a
735
722c

FIG. 6C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812
816
814
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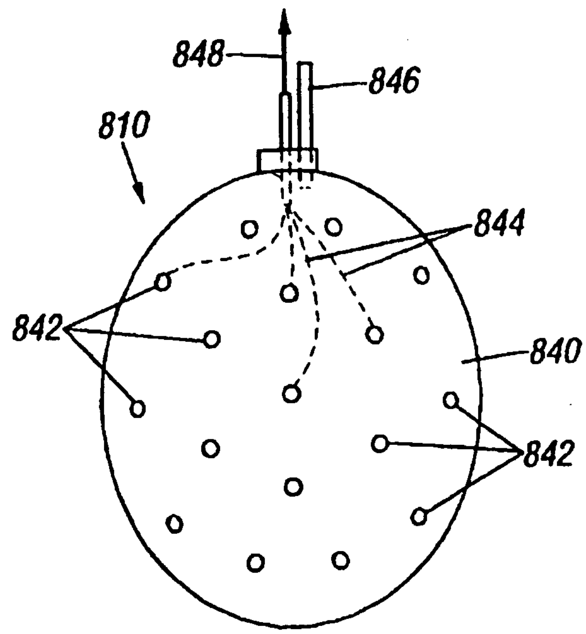
846
860
810
849
823

FIG. 6D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846
810
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842
840
842

FIG. 7

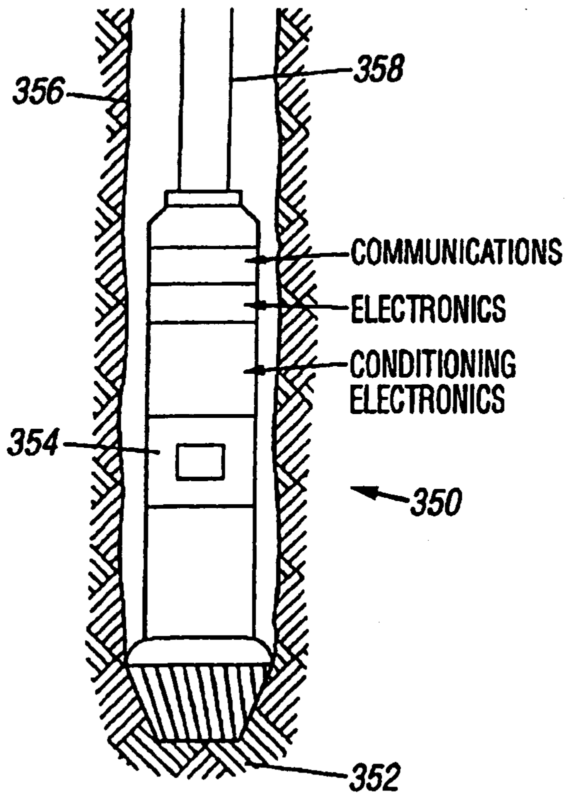
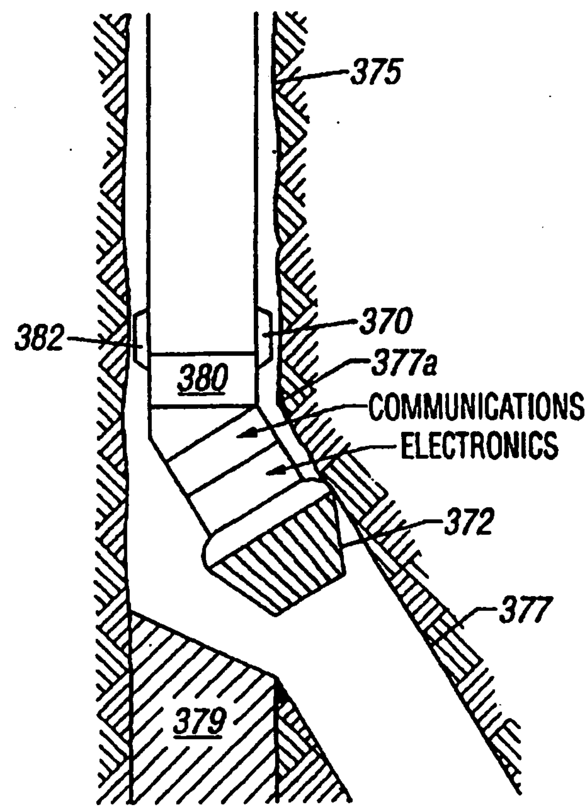

356
358
COMMUNICATIONS
ELECTRONICS
CONDITIONING ELECTRONICS
354
350
352

FIG. 8A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382
370
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377a
COMMUNICATIONS
ELECTRONICS
372
377
379

FIG. 8B

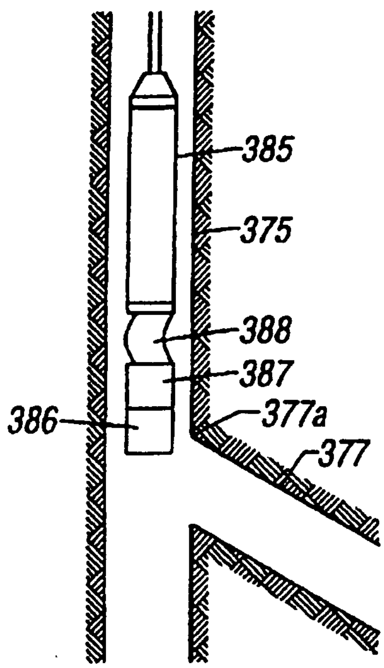



FIG. 8C

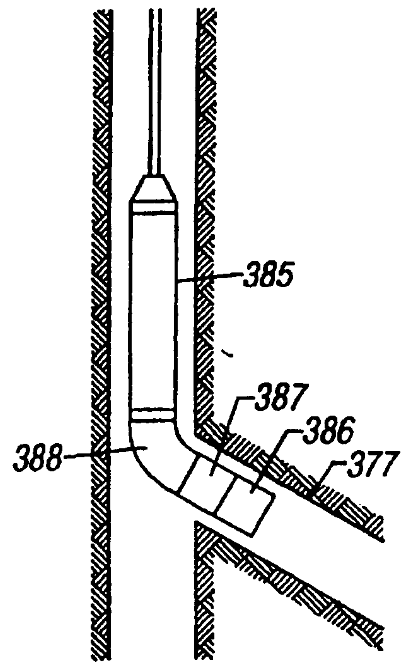



FIG. 8D

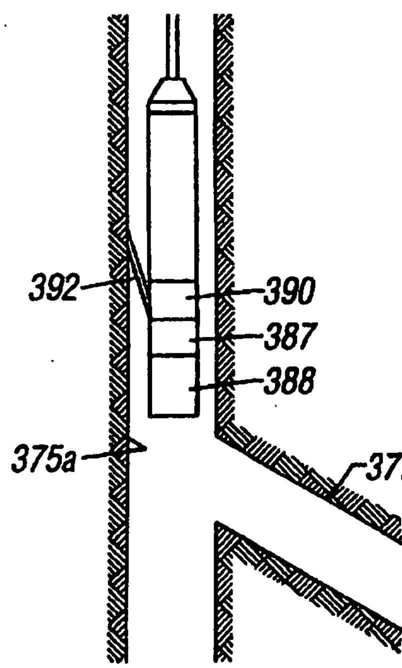
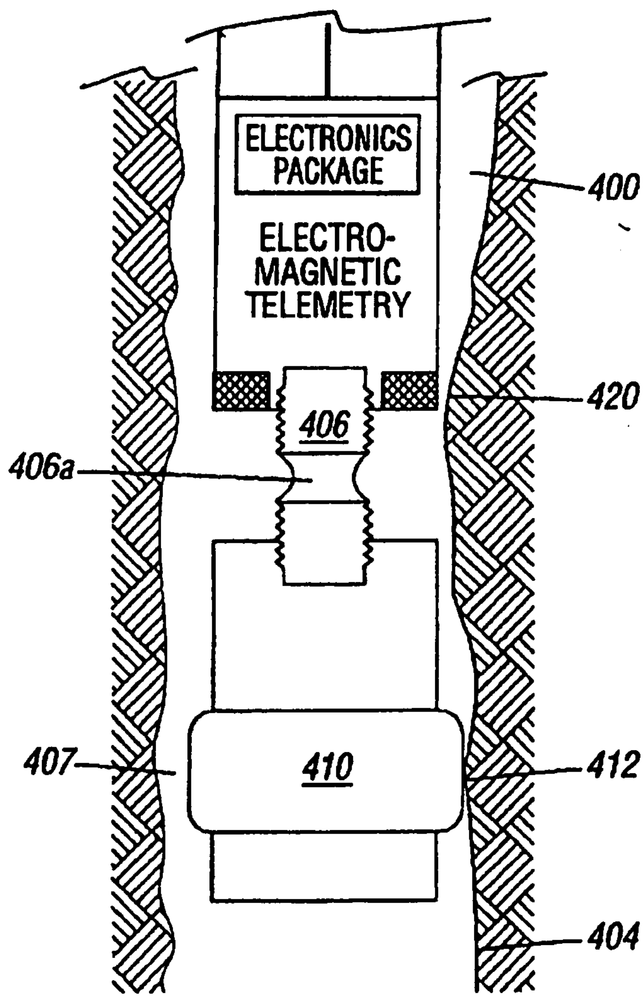


FIG. 9


ELECTRONICS PACKAGE
ELECTRO-MAGNETIC TELEMETRY
400
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406
406a
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412
404

FIG. 10A

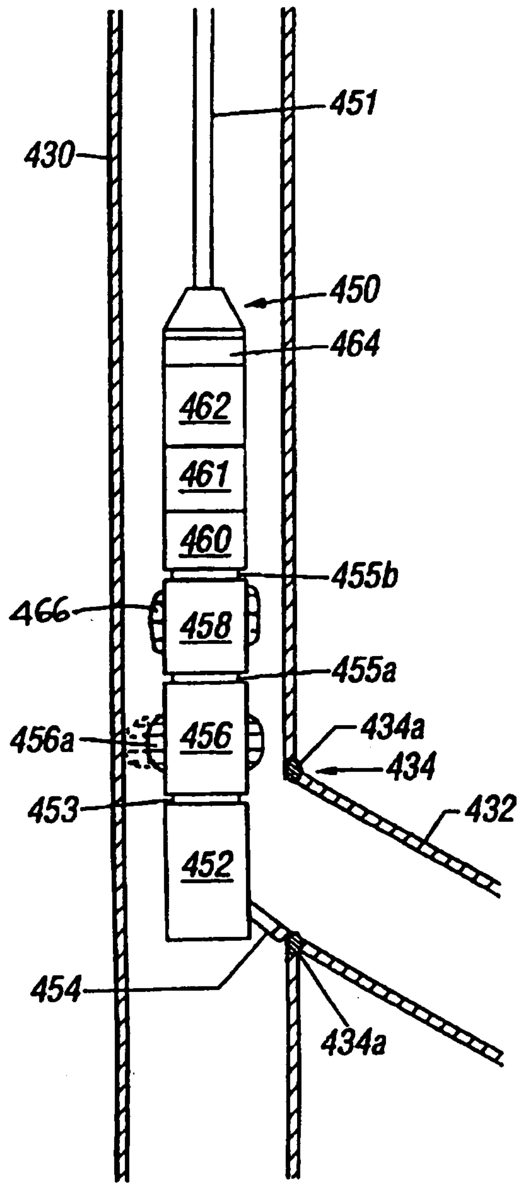



FIG. 10B

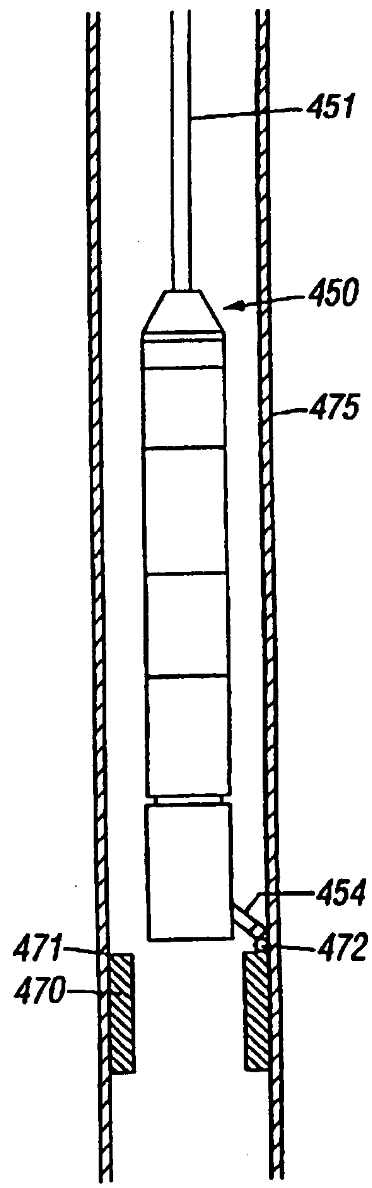
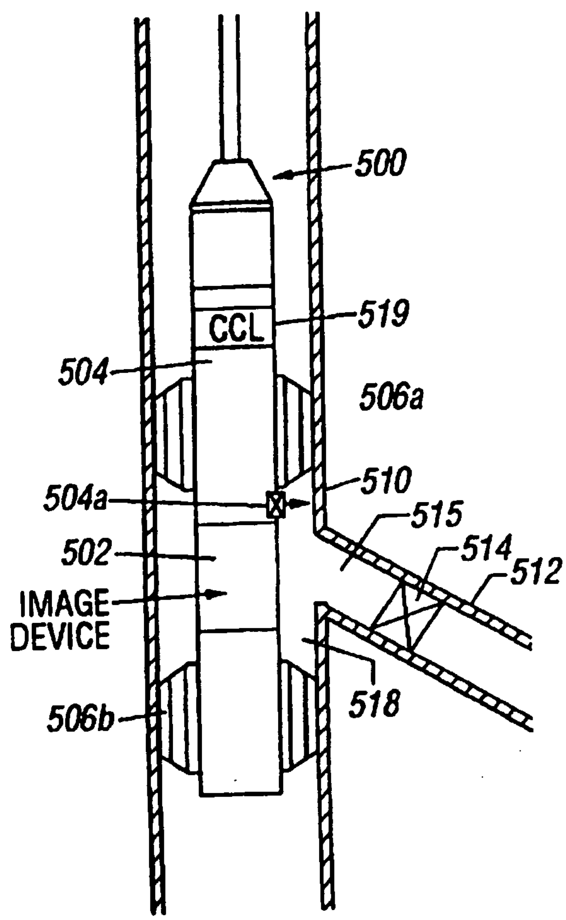


FIG. 11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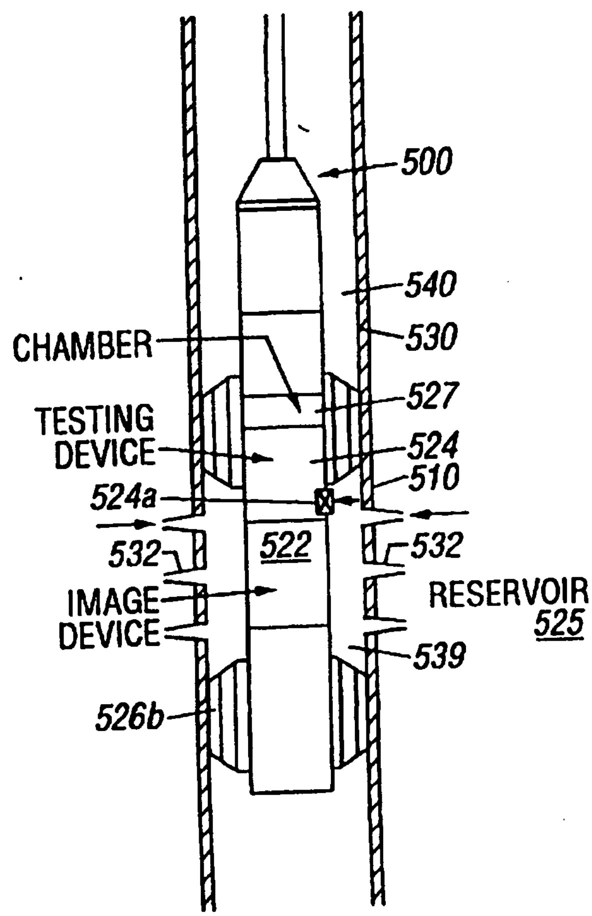
CCL
519
504
506a
510
504a
515
514
512
502
IMAGE
DEVICE
506b
518

FIG. 12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540
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CHAMBER
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TESTING
DEVICE
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524a
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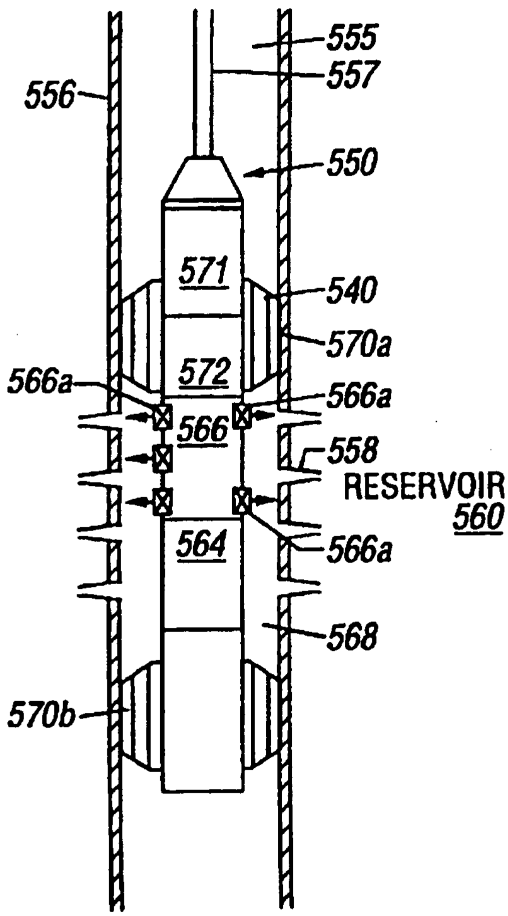
532
532
IMAGE
DEVICE
RESERVOIR
525
539
526b

FIG. 13


555
557
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570a
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566a
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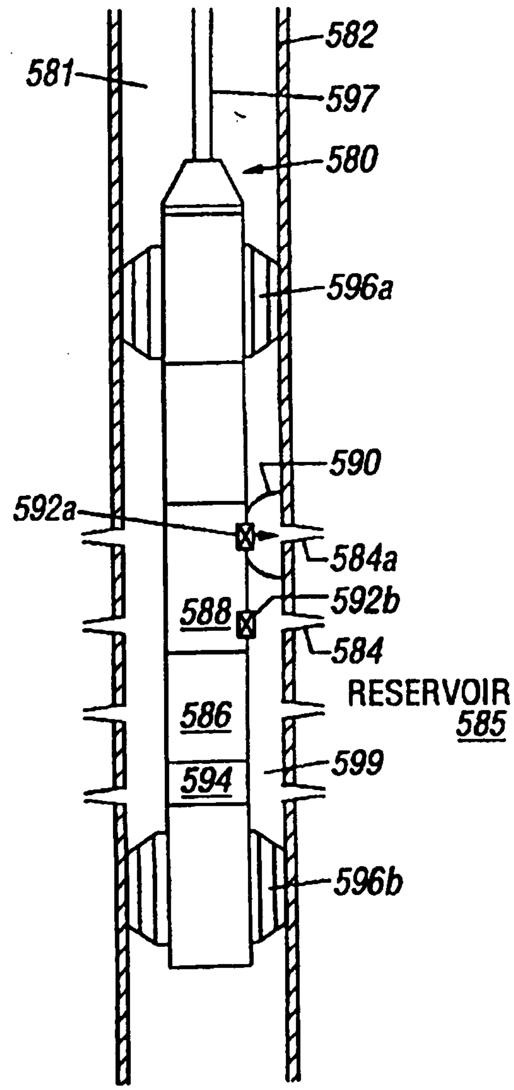
558
RESERVOIR
560
564
566a
568
570b

FIG. 14


582
581
597
580
596a
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592a
584a
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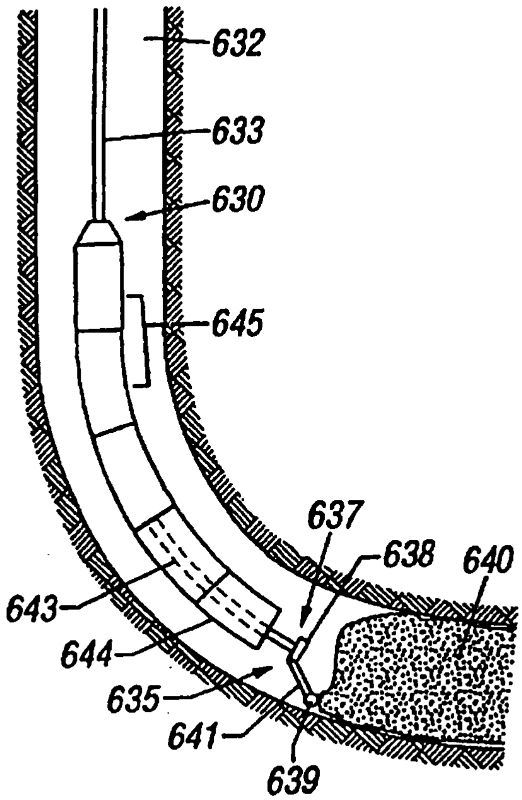
592b
584
RESERVOIR
585
586
599
594
596b

FIG. 15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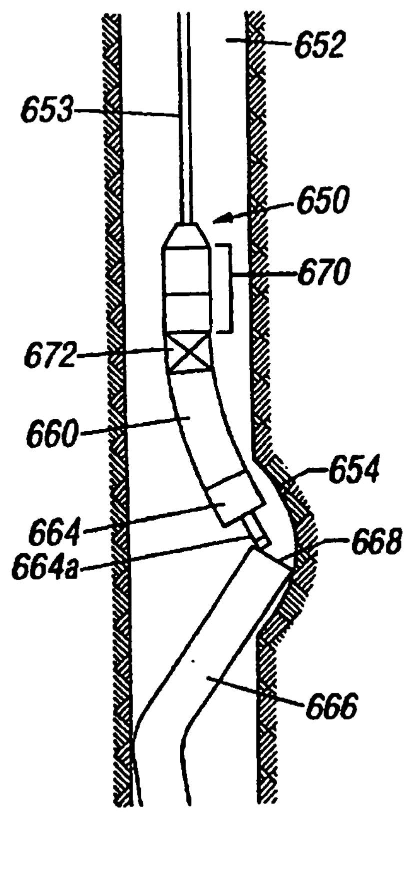
641
639

FIG. 16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654
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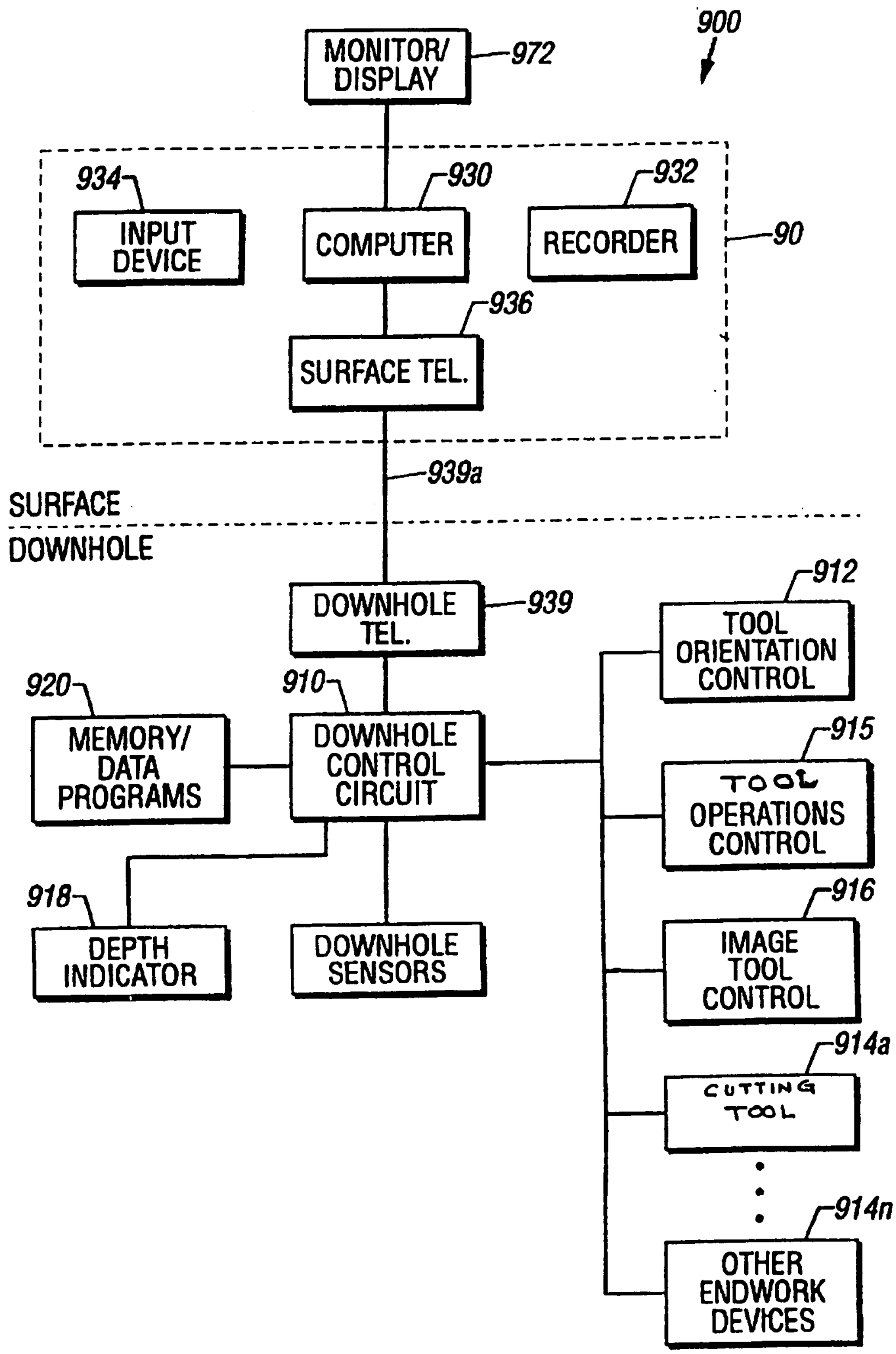
664a
668
666

FIG. 17


900
MONITOR/ DISPLAY
972
934
INPUT DEVICE
930
COMPUTER
932
RECORDER
90
936
SURFACE TEL.
939a
SURFACE
DOWNHOLE
DOWNHOLE TEL.
939
912
TOOL ORIENTATION CONTROL
920
910
MEMORY/ DATA PROGRAMS
DOWNHOLE CONTROL CIRCUIT
915
TOOL OPERATIONS CONTROL
918
DEPTH INDICATOR
DOWNHOLE SENSORS
916
IMAGE TOOL CONTROL
914a
CUTTING TOOL
914n
OTHER ENDWORK DEVICES

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/12524

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 E21B47/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | GB 2 270 099 A (HALLIBURTON CO) 2 March 1994<br>see the whole document<br>--- | 1,29-34, 36,38, 41,44, 55,56, 58,63 |
| A | GB 2 129 350 A (COLEBRAND LTD) 16 May 1984<br>--- | 1-8, 29-33,63 |
| A | FR 2 664 327 A (CLOT ANDRE ;TURON ROLAND (FR); UNGEMACH PIERRE (FR)) 10 January 1992<br>see the whole document<br>--- | 1,29, 44-56,63 |

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 16 October 1997 | 23.10.97 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Fonseca Fernandez, H |

Form PCT/ISA/210 (second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Inte. ..onal Application No
PCT/US 97/12524

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| P,A | EP 0 753 647 A (DORYOKURO KAKUNENRYO ;TAISEI KISO SEKKEI CO LTD (JP); RAAX CO LTD) 15 January 1997<br>see the whole document<br>--- | 1,38-40 |
| P,A | WO 97 12113 A (NATURAL RESERVES GROUP INC) 3 April 1997<br>see the whole document<br>--- | 1,29,34, 35 |
| A | US 5 153 718 A (MASSAR JACK) 6 October 1992<br>--- | |
| A | US 3 984 627 A (GALERNE ANDRE) 5 October 1976<br>--- | |
| A | US 4 774 573 A (MOUNT II HOUSTON B ET AL) 27 September 1988<br>--- | |
| A | US 3 596 582 A (SAYER WAYNE L) 3 August 1971<br>----- | |

1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter. .onal Application No
PCT/US 97/12524

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| GB 2270099 A | 02-03-94 | US 5485745 A | 23-01-96 |
| | | GB 2275953 A,B | 14-09-94 |
| | | NL 9301512 A | 05-04-94 |
| | | NO 933041 A | 02-03-94 |
| GB 2129350 A | 16-05-84 | NONE | |
| FR 2664327 A | 10-01-92 | NONE | |
| EP 0753647 A | 15-01-97 | JP 9021754 A | 21-01-97 |
| | | CA 2180883 A | 11-01-97 |
| WO 9712113 A | 03-04-97 | AU 7372096 A | 17-04-97 |
| US 5153718 A | 06-10-92 | NONE | |
| US 3984627 A | 05-10-76 | NONE | |
| US 4774573 A | 27-09-88 | CA 1301304 A | 19-05-92 |
| US 3596582 A | 03-08-71 | NONE | |